THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE V. VOL. IX.

No. VI.—JUNE. 1912.

ORIGINAL ARTICLES.

I.—Radiolaria-bearing Rocks in the East Indies.

By J. B. Scrivenor, M.A., F.G.S.

HAVING read with great interest Mr. E. E. L. Dixon's remarks on the Radiolarian cherts of Gower in the November number of the Quarterly Journal of the Geological Society,[1] I am tempted to offer some notes on the occurrence of similar rocks in the Malay Peninsula and Archipelago, where Radiolaria-bearing rocks are known to be widespread.

The idea that Radiolarian cherts are not necessarily evidence of deep-sea conditions has been steadily growing for a long time, but no one, as far as I am aware, came to close grips with the problem of their origin in shallow water until Mr. Dixon read the paper referred to (I note that the date of reading was March 9, 1910). The theory of a Radiolarian 'lagoon-phase' is the first serious attempt to explain how Radiolarian cherts came to be formed in shallow water.

The foundations of the 'deep-sea' hypothesis having been undermined, it is only natural to inquire if, after all, any known outcrops of Radiolarian rocks are evidence of deep-sea conditions apart from the Barbadian rocks. An extremely interesting paper on this subject was published in 1909 by Professor Molengraaf concerning widespread Radiolarian rocks in Central Borneo, which Professor Molengraaf believes to be oceanic deep-sea deposits.[2] This paper is supplementary to a previous publication, and in order to appreciate its full significance we must go back some years. In 1902 Professor Molengraaf published the results of his explorations in Central Borneo during 1893–4.[3] In this volume the 'Danau formation' is described.[4] It comprises diabase-tuff, diabase-porphyrite, quartzite, chert, jasper, hornstone, clay-slate, and sandstone, the leading rocks being silicified and partly serpentinized diabase-tuff and jasper.[5] The jasper and hornstone were found to contain many Radiolaria, described by Dr. G. J. Hinde in an appendix. Their examination led to the conclusion that the rocks

[1] "The Carboniferous Succession in Gower, Glamorganshire, etc.": loc. cit., vol. lxvii, pp. 511–31, 1911.

[2] G. A. F. Molengraaf, "On Oceanic Deep-sea Deposits of Central Borneo": Proc. Roy. Acad. Amsterdam, vol. xii, pp. 141–7, 1909.

[3] *Geological Explorations in Central Borneo*, English edition, London, 1902.

[4] pp. 414–21.

[5] Op. cit., p. 414.

were pre-Cretaceous and probably Jurassic, and Professor Molengraaf was of the opinion that the presence of the Radiolaria, combined with the great extent of the beds containing them, at least 230 kilometres, stamped those beds as deep-sea deposits. Professor Molengraaf, however, is careful to say that the presence of pelagic organisms alone is not conclusive proof of oceanic deposits, "for we know that in certain localities close to the coast where, through peculiar conditions, the deposition of terrigenous materials on the ocean floor was entirely or almost entirely prevented, even at a short distance from the shore, deposits are found which may be composed exclusively of remains of pelagic living organisms." These conditions were thought too unlikely to extend for 230 kilometres. On p. 418 Professor Molengraaf says in a footnote that the sandy shales and clay-slates are too much folded and disturbed for him to say with certainty whether they lie on top of or below the chert, but they appeared to be above it. Finally, after sketching the extent of the Danau formation, Professor Molengraaf refers to some deposits in Sambas, a province of West Borneo, with the same trend as the Danau formation and comprising a complex of cherts.[1] He adds: "Should the cherts of Sambas prove to be of the same age as those of the Danau formation, Radiolaria will doubtless be found in them if searched for."

In 1904 Mr. Wing-Easton's work[2] on part of West Borneo, including the greater part of Sambas, was published. Radiolaria were found in Upper Triassic, Jurassic, and Cretaceous rocks, many being located in Sambas, but the rocks containing them are not described as cherts as understood by us. Thus, on p. 25 we find in connexion with the Upper Trias: "On the other hand there are in the vicinity of the quartz-porphyries hard beds rich in silica and often with Radiolaria, which must be explained as ashy deposits of the above-named eruptive rocks, and which are very like quartzites when light-coloured or 'kieselschiefer' when dark." These Upper Triassic beds are referred to again on p. 233. On pp. 271, 272, and 275 Jurassic rocks with Radiolaria are mentioned. It is stated that Radiolaria occur in a hard rock which can only be determined as a 'kieselschiefer'. No mention is made of 'hornstein' or 'radiolarienjaspis' except in reference to Professor Molengraaf's rocks (p. 40).[3] The other Jurassic rocks containing Radiolaria are marl and limestone. Among the Cretaceous rocks Radiolaria were found in marl, limestone, siliceous propylite-tuff, and *sandstone*. The most important remarks, however, that Mr. Wing-Easton makes about the Radiolaria-bearing beds are to be found on pp. 40 and 41, where it is emphatically stated that the Jurassic and Cretaceous beds were deposited in shallow water near a coast, and the same view is held, apparently, for the Upper Triassic rocks.

Nevertheless, Professor Molengraaf in his 1909 paper does not qualify his previously expressed views about the deep-sea origin of

[1] p. 421.

[2] "Geologie eines teiles von West Borneo": Jaarb. v. h. Mijnwezen in Neder. Oost-Indië, Weten. Gedeelte, 1904.

[3] Verbeek, however, uses 'kieselschiefer' for chert. See below.

the Central Borneo cherts and hornstones, but produces fresh evidence to show that the Radiolarian rocks extend eastwards for 650 kilometres and cover about 40,000 square kilometres, the composition of the cherts and hornstones remaining perfectly constant throughout. In the map accompanying this paper the Radiolarian rocks are shown striking towards the southern part of Sambas, where Mr. Wing-Easton found Upper Triassic, Jurassic, and Cretaceous Radiolaria-bearing rocks. One would not expect, therefore, to find such divergent views regarding the origin of the Radiolarian rocks in Central and West Borneo, but the difference of the lithological characters of the rocks described by the two authors is so evident that it is difficult to believe that the West Borneo rocks are really an extension of those in Central Borneo.

Another instance of Radiolarian chert being considered evidence of deep-sea conditions is afforded by a rock found in the island of Billiton and described by Dr. Hinde.[1] Dr. Hinde declares for deep-sea conditions on the palæontological evidence, but in the text Dr. Verbeek gives some significant information regarding this rock.[2] It came from the bed-rock of a certain mine, and occurred as a bed about half a metre thick between sandstones and clay-slates.

My own experience of Radiolaria-bearing rocks in the East Indies has been in the Malay Peninsula and in Sarawak.

In the Malay Peninsula there is a series of rocks that I have called the Chert Series, consisting of chert beds with Radiolaria, too poorly preserved to be of homotaxial value, and very fine-grained shales. These shales are sometimes light grey or yellow in colour, and the chert is sometimes green or bright red like jasper, but a common feature of both chert and shales is the abundance of carbon. In the shales this is easily recognized, but in both shales and cherts it has been separated from the other rock constituents and proved to be carbon. In both rocks it has acted as a precipitant of metallic sulphides, and I have a specimen showing beautiful little casts of Radiolaria in pyrite.[3]

Another point that requires more than a passing mention about the Radiolarian cherts of the Peninsula is that where the best exposures occur, namely in Ulu Pahang and in Kedah, they are close to large outcrops of quartzite and conglomerate. They also occur, however, on the Pahang River associated with lavas and ashes.

At first sight it might be supposed that the cherts and accompanying shales are so closely connected with the arenaceous rocks, which have yielded marine fossils, as to be part of one big series comprising both cherts and quartzite, the one conformable to the other, but although this would not be very surprising in the light of

[1] R. D. M. Verbeek, "Geologische Beschrijving van Banka en Billiton," Appendix 1 by Dr. G. J. Hinde, pp. 223–7 : Jaarb. v. h. Mijnwezen in Neder. Oost-Indië, Weten. Gedeelte, 1897.

[2] p. 92.

[3] These rocks and their relation to other rocks are discussed in *The Geology and Mining Industries of Ulu Pahang*, Kuala Lumpur, 1911, ch. ix and xii, pls. v–vii, xiii, obtainable at the Malay States Information Agency, 88 Cannon Street, E.C.

experience elsewhere there are good reasons for supposing that the arenaceous rocks are separated from the cherts by an important unconformity. The evidence for this is as follows: The conglomerates contain abundant pebbles of chert identical with that in the Chert Series. It might be argued that these pebbles come from still older chert beds that are not visible on the surface now, but pebbles of the volcanic rocks with which the cherts are known to be associated on the Pahang River have also been found in the conglomerate. This points to the Chert Series as the source of the pebbles; and not only had the chert time to consolidate before it was included in the conglomerate, but some of the chert became traversed by veins before being denuded and rolled into pebbles. These facts indicate a considerable break in the record unless we assume, against all available information, that Radiolarian cherts can be deposited and consolidated with great rapidity. There is, moreover, a piece of negative evidence against a close connexion between chert and quartzite, which is that in the biggest outcrop of the quartzites and conglomerates, namely that stretching through the centre of Pahang, no chert has been seen *in situ*. Of course, it may be there nevertheless, but its apparent absence is worth mentioning.

The connexion of the Pahang cherts with volcanic rocks is interesting when one considers the arguments put forward lately by Mr. Dewey and Dr. Flett to supply a possible explanation of the association of Radiolarian cherts and spilites.[1] No evidence has been noticed yet of the albitization of the Pahang lavas, but it is conceivable that emanations from these eruptions, which were mostly submarine, supplied sufficient silica for a flourishing growth of Radiolaria without producing albitization. In Kedah, however, I cannot point to volcanic rocks associated with the chert as a possible explanation of the formation.

In Sarawak the Radiolaria-bearing rocks that I have seen are associated with Middle Oolite limestones and marls,[2] and also with shales that are probably not far removed in age from the limestones and marls. The Radiolaria were found in chert nodules in the limestone, in chert from a calcareous conglomerate, in indurated shales, and in a nodule in shale. The chert occurs in much the same way as flint in chalk, and contains but few recognizable Radiolaria. Some of the indurated shales, found as included fragments in an igneous rock, contain calcite and were probably calcareous shales or marl originally. Radiolaria are common in these fragments. At Santubong, however, on the coast, a few Radiolaria were found in beds of indurated shale associated with beds of sandstone and an occasional bed of ash. Thin sections do not show any reason for supposing that the indurated beds were originally ash of very fine grain.

The nodule containing Radiolaria was found in shale on the Sarawak River at the landing-place for the Bau gold-mines (Bau *penkalan*).

[1] "British Pillow-lavas and the Rocks associated with them": GEOL. MAG., 1911, pp. 244–6.

[2] R. B. Newton, GEOL. MAG., 1897, p. 415.

It suggests a septarian nodule, but is dull black in colour, and in section shows a brown isotropic base crowded with Radiolaria, sponge spicules, and pyrite. The Radiolaria are mostly calcite casts, but some are partially replaced by pyrite.

Comparison of the above-mentioned Rocks.

Apart from the Radiolarian nodule in shale on the Sarawak River, the origin of which I am at a loss to explain, it would appear that the rocks in Sambas and the rocks in Sarawak containing Radiolaria were deposited under similar conditions, and probably in the same sea, not far from the coast. None of the Sarawak rocks, however, excepting the nodule, can be cited as examples of rocks composed chiefly of Radiolaria. They are not Radiolarian rocks, but rocks containing some Radiolaria, mingled with abundant other organisms in the case of those associated with the limestones.

This, however, is not the case with the Central Borneo and Peninsular cherts, which are distinctly Radiolarian rocks. Professor Molengraaf claims that those in Central Borneo are oceanic, abyssic sediments, but as regards those in the Peninsula I do not see any good reason to believe that the cherts were laid down in an abyss of the ocean, but think rather that a sudden change in conditions apart from depth led to the establishment of a flourishing colony of siliceous-shelled organisms in a sea where hitherto limestone rich in corals and Cephalopods and other calcareous shells had been forming. These cherts are not silicified limestones.

On comparing these two occurrences of Radiolarian rocks, however, we find that there is a considerable lithological difference. Professor Molengraaf[1] thus describes the Central Borneo rocks :—

"The first type is the Radiolarian hornstone, the true Radiolarite. This rock is semi-transparent, hard, brittle, and splintery, and of a colour varying between milkwhite, red, and greenish. It consists of about 97 per cent of silica and is composed almost exclusively of closely-packed tests of Radiolaria, joined together by a siliceous cement. The red-coloured varieties may be called Radiolarian jasper; they contain a small percentage of iron. The tests of the Radiolaria are difficult to distinguish under the microscope in the milkwhite varieties; they can be much better distinguished in the red jasper varieties, but best of all they are preserved and discernible in the greenish varieties of the Long Keloh in the Berau district.

"The second type is an argillaceous chert or siliceous clay-shale, which is always coloured bright red and contains more clay and iron and less silica than the first type. Radiolaria occur in it in variable quantity, but always much less than in the first type.

"The two types pass one into the other quite gradually, and all sorts of intermediate types occur. The distinct stratification of the cherts of the Danau formation is caused by thicker strata of pure Radiolarian hornstone alternating with thin layers which contain more clay and less Radiolaria.

"Both types and all intermediate stages agree in this respect, that

[1] G. A. F. Molengraaf, "On Oceanic Deep-sea Deposits of Central Borneo": Proc. Roy. Acad. Amsterdam, vol. xii, pp. 142–3, 1909.

they do not contain any constituents indicative of a terrigenous origin, and that the organic remains they contain all belong to Plankton organisms with siliceous tests, chiefly Radiolaria.

"In an uncemented state, in which such deposits are still continually laid down on the bottom of the oceans at the present day, the deposits of the first type are called Radiolarian ooze and those of the second type red clay. Radiolarian ooze and red clay gradually pass one into the other, and only differ in the percentage of organic remains they contain. Murray, for instance, places the limit between red clay and Radiolarian ooze at a point where 20 per cent of the deposit consists of tests of Radiolaria."

In the Peninsula, on the other hand, but for a few occurrences near Bentong (Pahang) of red and green chert, the Radiolarian rocks differ markedly from the Central Borneo rocks in being dark grey or black, owing to the abundance of carbon, which is sometimes so thick as to render a thin section almost opaque. The presence of this carbon and the presence of carbon in the limestone referred to above also suggest that whatever its source the limestone and chert have at least one point in common in their mode of formation, and the abundance of carbon in the cherts marks them off as something distinct from the Central Borneo rocks.

The presence of carbon in Radiolarian chert has been noted before, but I have not any recollection of remarks as to its significance. Thus in 1899 Professor T. W. E. David and E. F. Pittman mentioned streaks of carbon in chert found in New South Wales.[1] Dr. Hinde says the supposed carbonaceous matter may be partly ferruginous. Again, in the cherts of the Lower Culm Measures of England, Dr. Hinde and Mr. Howard Fox mention carbonaceous or ferrous material[2] as being in part the cause of fine lamination. These authors also mention rhombohedral casts, found in the cherts. These casts occur sometimes in the Peninsular cherts and in the Billiton chert, the latter of which Dr. Hinde says contains a dust of ferrous or carbonaceous origin.[3]

The origin of the carbon in the Peninsular cherts is doubtful, but it is significant that in some specimens cell-structures have been found believed to be the remains of algæ (*vide* plate vii of the publication on the Geology and Mining Industries of Ulu Pahang).[4] Moreover, the shales associated with the Peninsular cherts cannot be regarded as devoid of terrigenous matter. Like the shales with the limestone they appear to consist of very fine sediment. The presence of Radiolaria in them has only been proved in the case of those rich in carbon.

Anyone who reads Professor Molengraaf's views on the Central Borneo rocks will realize that his case for their being oceanic deposits, in the same sense as the deposits of Barbados are oceanic, is so strong that those who would question it must examine the relations of the

[1] Q.J.G.S., vol. lv, p. 34.
[2] Q.J.G.S., vol. li, pp. 629–31, 1895.
[3] Op. cit., p. 223.
[4] I am indebted to Mr. H. N. Ridley, F.R.S., for examining these specimens, and to Dr. Hinde for examining cherts with Radiolaria found in Singapore, but not *in situ*.

rocks in the field. The Peninsular cherts on the other hand, and probably the Billiton chert also, were laid down in a comparatively shallow sea, not out of the reach of terrigenous material. The oceanic Radiolarian rocks are not stated to contain any carbon; the shallow-water Radiolarian rocks are rich in carbon.

Dr. Hinde has also described Radiolaria from Triassic and other rocks in Timor, Rotti, Savu, Ceram, Celebes, Buru, and Mangoli. They are not stated to contain carbon, being light-grey and reddish cherts. Very little is known of their field relations.[1] Dr. Verbeek mentions, however, on p. 320, "*roches triasiques, des calcaires à halobies, des grès et de la lydite à radiolaires,*" as occurring on Savu, and on p. 325 says, "*les argiles renferment des radiolaires*". These clays are between marls. This association of rocks certainly points to shallow-water conditions, and it would be interesting to know, in the event of extensive exposures of the Radiolarian cherts being found, if they contain carbon in any quantity.

Origin of the Peninsular Carbonaceous Radiolarian Cherts.

Two suggestions have been put forward to account for the formation of Radiolarian cherts near a coastline: Messrs. Dewey & Flett's suggestion that favourable condition were caused by emanations from a volcanic source, and Mr. Dixon's 'lagoon-phase'. The former cannot be applied to every case; it cannot, for instance, be applied to the Gower cherts. The latter, valuable though it is, lacks, as far as I am aware, the support of known modern examples where Radiolarian beds are being formed.

Messrs. Dewey & Flett have put forward an explanation for some cases, and it remains to find for other cases, such as the Peninsular carbonaceous cherts, where not associated with igneous rocks, a reason for the change from calcareous to siliceous deposits. Whether this change is connected with a lagoon-phase or not, the key to the problem seems to be how sea-water became so charged with silica in solution as to diminish the growth of calcareous organisms forming beds of limestone, and to promote the growth of siliceous organisms. In the absence of volcanic emanations it is just possible that such a condition may be brought about by tropical weathering and rivers discharging into closed or nearly closed seas.

Certain researches that arose out of a question concerning 'laterite', now nearing completion, coupled with previous observations, have emphasized the fact that the most remarkable result of weathering in the Peninsula, as far as widespread effects are concerned, is the removal of silica in solution in enormous quantities. The power of ground-water to dissolve silica is such that quartzite, of which rock there are extensive outcrops, weathers back to sandstone for a considerable depth, and granitic rocks are rendered clayey by the removal of the finer quartz particles and the breaking down of the felspars. There is no evidence to show that the bulk of this dissolved silica does not find its way out to sea, but with it there must go quantities of

[1] *Vide* "Rapport sur les Moluques", R. D. M. Verbeek: édition française du Jaarb. v. h. Mijnwezen in Neder. Oost-Indië, vol. xxxvii, partie scientifique, p. 709, 1908.

lime also, derived from calcareous rocks, also powerfully attacked by ground-water, even under a thick covering of argillaceous and arenaceous rocks. Given a tropical country, however, in which the ground-water acted on siliceous rocks only, a not impossible state of affairs, then it might be that the sea-water would become so charged with silica that siliceous organisms would flourish, while calcareous organisms would diminish.

The most favourable conditions for accumulations of such siliceous organisms to form cherts would be found near or beyond the limit of the finest detritus brought down by the rivers. Within the area of sedimentation we could expect rocks with some Radiolaria to be formed, such as the Sarawak indurated shales and the shales of the Upper Gondwanas near Madras, described by Mr. Coomaraswamy.[1]

This suggestion of the necessary supply of silica having been afforded by tropical weathering is, of course, no less speculative than the other suggestions, but, as a third possible cause of the formation of Radiolarian cherts in shallow seas, it may be of interest. In conclusion I would put forward the two following propositions:—

1. The presence of abundant carbon in Radiolarian cherts appears to be an indication that such cherts are not of deep-sea origin.

2. Large quantities of silica in solution, supplied by tropical weathering of siliceous rocks, may have promoted, or helped to promote, the abundant growth of Radiolaria in shallow seas.

II.—The New Mountain of the Year 1910, Usu-san, Japan.

By E. B. Bailey, B.A., F.G.S.

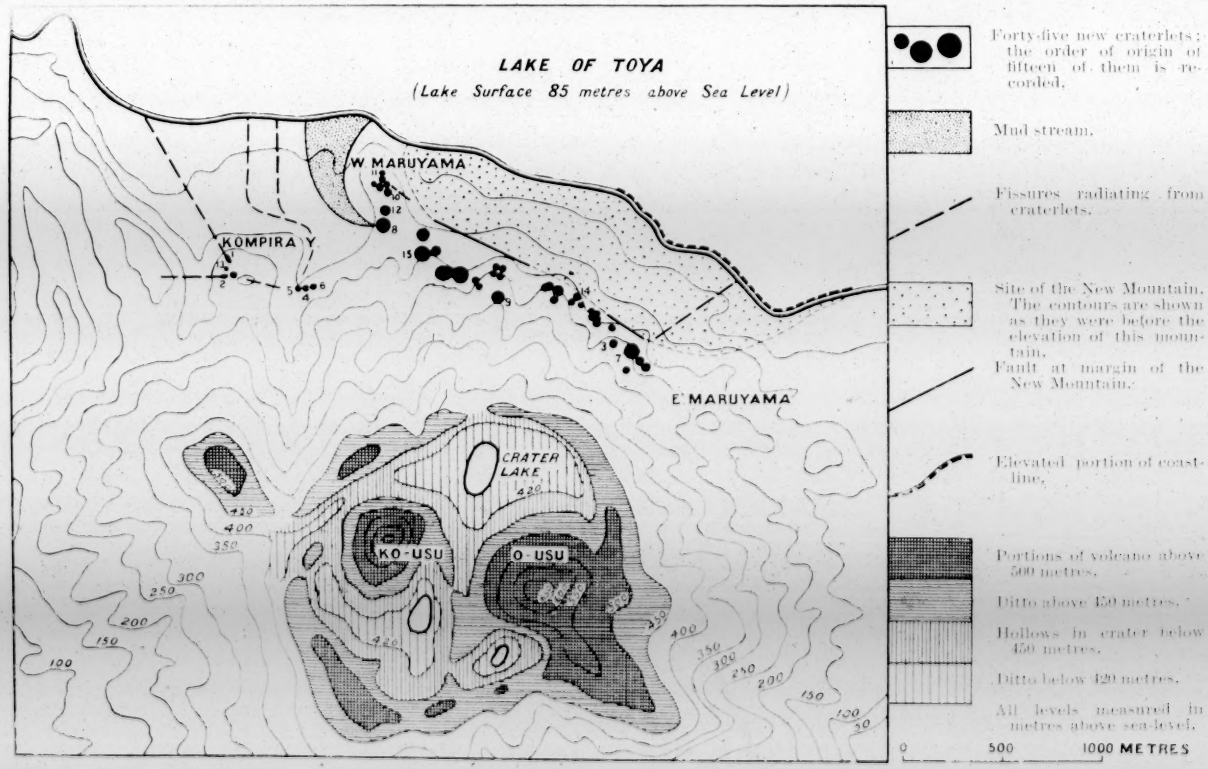
(PLATES XII AND XIII.)

THE writer's attention was directed to Dr. Omori's[2] description of the 1910 eruption of Usu-san through a review which appeared in *Nature* (1911, p. 221) from the pen of Professor Milne, F.R.S. The following pages constitute a *résumé*, rather than an additional review, and are justified on account of the interest of Omori's observations to many geologists who may not find it convenient to consult his original paper. All three figures here published have been redrawn for the purpose. Plate XII is based on a coloured map, and Plate XIII on photographs which have already been reproduced by Professor Milne in his review.

Usu-san is one of a group of volcanoes situated in the south-western peninsula of the island of Yezo, Japan. It is bounded on the south by the sea, and on the north by the Lake of Toya—a circular lake some 10 km. in diameter and 187 m. in depth. The distance of the centre of the volcano from the nearest point of the sea is 4·7 km., and from the lake 2·2 km.; in fact, the situation could not be more convenient than it is for dealing with questions involving measurement of changes of level.

[1] Geol. Mag., 1902, pp. 305, 306.

[2] F. Omori, "The Usu-san Eruption and Earthquake and Elevation Phenomena": Bulletin of the Imperial Earthquake Investigation Committee, Tokyo, vol. v, No. 1, pp. 1–38, pls. i–xiii.


LAKE OF TOYA
(Lake Surface 85 metres above Sea Level)
W MARUYAMA
KOMPIRA Y
E MARUYAMA
CRATER LAKE
KO-USU
O-USU
Forty-five new craterlets: the order of origin of fifteen of them is recorded.
Mud stream.
Fissures radiating from craterlets.
Site of the New Mountain. The contours are shown as they were before the elevation of this mountain.
Fault at margin of the New Mountain.
Elevated portion of coastline.
Portions of volcano above 500 metres.
Ditto above 450 metres.
Hollows in crater below 450 metres.
Ditto below 420 metres.
All levels measured in metres above sea-level.
0 500 1000 METRES

Map of Usu-san, Japan.

The main features in the topography of the mountain are summarized in the map, Plate XII. It will be noticed that two prominent summits, O-usu and Ko-usu, rise within the crater hollow. These two are apparently of prehistoric origin, but are ascribed by Omori to "the pushing up of molten lava mass which solidified during the process". A neighbouring volcano, Tarumai-san, built up a similar lava-dome, 134 m. high, during an eruption which lasted three months of the year 1909. Kompira-yama and the East and West Maru-yamas, on the northern flanks of Usu-san, are also regarded as lava-domes, but evidence in regard to their geological relationships is very meagre, since the whole of the lower portion of the volcano is swathed in soil of great depth. The crater of Usu-san took no part in the 1910 eruption, but Kompira-yama and West Maru-yama were both the sites of active explosions.

There are records of previous eruptions at Usu-san for the years 1663, 1769, 1822, and 1853. In the case of both the 1663 and 1822 eruptions, of which detailed accounts have been preserved, we learn that earthquakes preceded any smoke-explosions by an interval of about three days. The occurrence of warning shocks of this character was a feature once more of the 1910 eruption, and seems to be characteristic of volcanic action in general, at any rate in Japan. In other respects Omori has no analogy to point to between the early eruptions and that of 1910. For convenience of description the phenomena of this last eruption may be grouped under three main headings: (1) earthquakes, (2) explosions, and (3) elevation.

(1) Earthquakes were first felt on July 21, and obtained their maximum frequency during the fifteen hours which elapsed between 6 p.m. on the 24th and 9 a.m. on the 25th. They then fell off rapidly, and in fact were only about half as numerous by the time of the first explosion, 10 p.m. on the 25th. They continued on the decrease the following day also, but thereafter remained irregularly constant during the ensuing months of active eruption.

The earthquakes which preceded the first explosion were not only more frequent than those which followed it, but also more severe. The strongest shock occurred at 3.49 p.m. on the 24th, and the next strongest at 4.39 p.m. on the 25th. A small amount of damage resulted from these disturbances in Abuta, a town 6 km. distant from Usu-san; but, in accordance with the general rule for volcanic earthquakes, neither shock was of really destructive violence, considered, that is, in relation to wooden buildings of Japanese type. The main earthquake penetrated as a sensible tremor to a distance of 60 km. towards the north-east and 140 km. towards the south-west.

(2) As already stated, the eruption proper was initiated by an explosion at 10 p.m. on July 25. The outburst was a single small affair, and took place on the north-west side of Kompira-yama. Ashes and rock fragments were discharged, and a rude crack fashioned in the soft earth of the hillside (numbered 1, Plate XII). Other eruptions from new foci followed at short intervals, some of them enjoying a paroxysmal career of several days duration. By August 10 the number of craterlets had increased to at least twenty-eight. The opening up of fresh orifices continued, though with diminished vigour,

till the end of the year. By November 12 the forty-five craterlets shown on Plate XII had been blasted out. The relative order of formation of a non-consecutive fifteen from among these forty-five was observed, and is shown by the use of numbers on the map. The data thus afforded are sufficiently complete to indicate that there was no simple connexion between the sequence of the explosions and the spatial distribution of the resulting eruptive centres.

All the different craterlets were formed in the thick layer of soft earth to which reference has previously been made. Many of the eruptions proceeded quite quietly and were unaccompanied either by loud detonations or recognizable earthquakes. Ashes and stones were ejected, but never any lava, and 'volcanic fires' are only reported in the case of the first explosion. The majority of the craters had a very brief activity, and after having thrown out clouds of ashes and stones for a few hours, or a day, were then reduced to complete rest. Some, however, persevered for several days and gradually enlarged their diameters to over 200 metres. The spectacle presented by the eruption, as illustrated in Omori's photographs, was often singularly grand with several craterlets in operation at the same time, tossing up smoke and stones 500 m. high into the air. A craterlet at the base of West Maru-yama was somewhat exceptional in its behaviour, for it poured out hot steaming mud after each of its major outbursts; and eventually this mud accumulated to such an extent that it covered a triangular area 800 m. long and 450 m. in base.

Plate XII shows the orderly arrangement of the craterlets and Fig. 1, Pl. XIII, their general appearance. It seems natural to regard them as falling into two divisions, a main group peripheral to the region of elevation and a satellitic group on Kompira-yama. Omori, however, classifies them in three divisions: an arcuate group, concentric with the great crater of Usu-san, and reaching from the flanks of East Maru-yama westwards to the craterlet numbered 5, and two radial groups, the one extending along Kompira-yama and the other along West Maru-yama. There is no need to dwell upon this difference of classification, for it is a mere matter of detail, since Omori is perfectly definite in connecting the origin of the craterlets with the phenomena of elevation which now fall to be described.

(3) The elevation of the New Mountain is the main feature of interest in the 1910 eruption of Usu-san. It first manifested itself in the behaviour of Lake Toya. Thus, in spite of a light rainfall, the waters of the lake rose more than a foot above their usual level in the latter part of July, that is about the time of the commencement of the eruption, and maintained themselves in this position throughout the following month of August. The accompanying rise in the Sobets River, the only outlet of the lake, meanwhile amounted to 2 feet. This apparent increase of the waters of Lake Toya was of a general character and presumably due to a differential upward displacement of some portion of the lake bottom. That local movement of the type required did occur was in fact demonstrated on August 6, when Omori found that a reach of the coastline about a mile long at the foot of East Maru-yama had been elevated nearly a metre out of the water. To study this

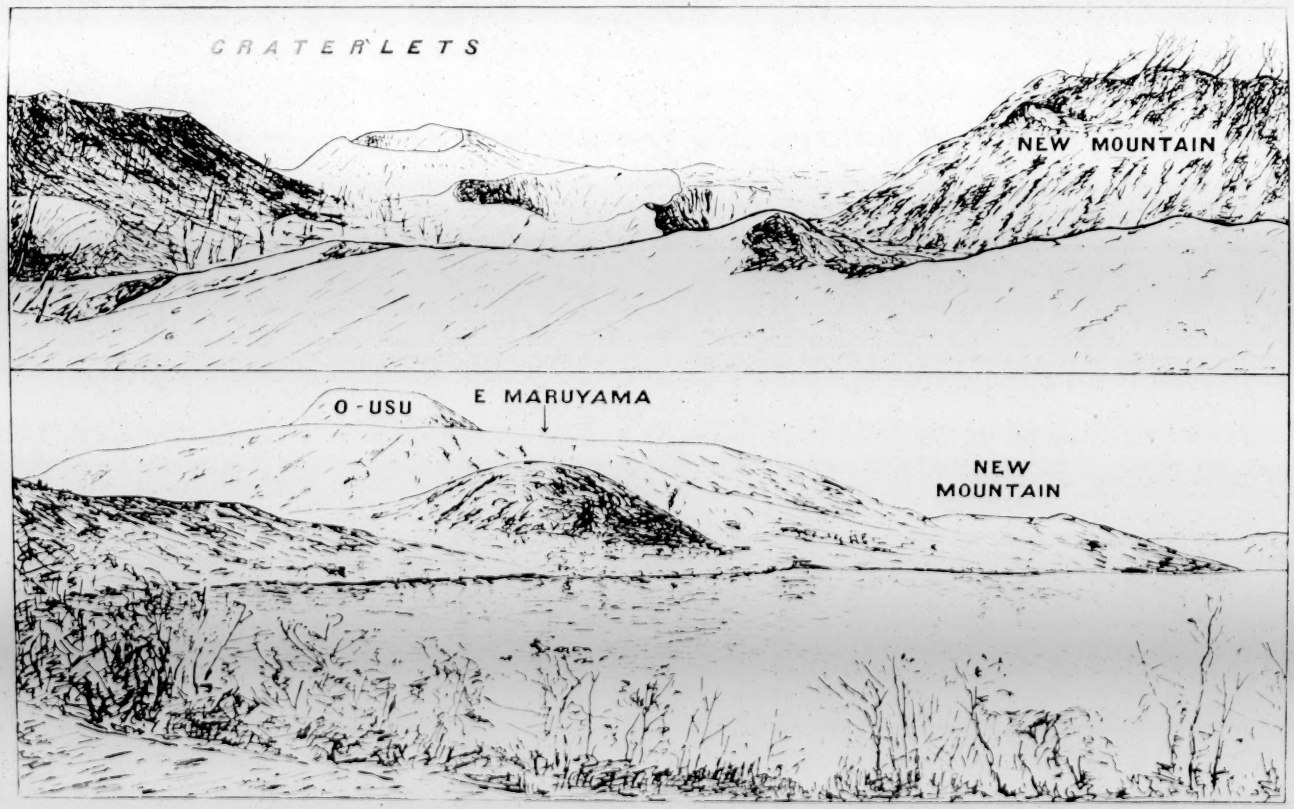


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FIG. 1. Fault-face of the New Mountain with tilted trees on top; to the left craterlets formed during the period of elevation.
,, 2. Usu-san with the New Mountain as seen from across the Lake of Toya.

phenomenon more precisely a graduated level-gauge was at once erected in the lake near the east end of the elevated stretch of coast, and two others at convenient points on either side of the disturbed tract. The two control gauges gave concurrent results, so that it was a simple matter to interpret very precisely the differential movement indicated by the instrument situated in between. It is extremely interesting to find that part of the elevation thus determined proved to be of a transient nature. From August 6 to August 21 an elevation of 34·3 cm. was recorded (additional to that which had occurred previous to the former date). A slight drop was then experienced, but the same height was attained once more on August 27. Thereafter a gradual uneven downward movement set in, and by November 10 the lake bottom at the point investigated stood merely 16·7 cm. higher than on August 6.

Meanwhile a large inland tract, about 2,700 m. long and 600 m. wide, was upheaved. At two places along its inner margin it was bounded by a definite fault-face (Plate XII), and it was at the more westerly of these two localities that the elevation was most pronounced (Plate XIII). Here Omori found the inside of the New Mountain defined by a steaming dislocation surface about 94 m. in height and inclined outwards towards the south at angles varying from 30° to 60°. This face, extensive as it was, is said to have consisted entirely of soil with embedded fragments of rock.

The first stages of the elevation passed unnoticed; in fact, it was not till August 20 that the appearance of the New Mountain attracted general attention. The elevation continued to increase till November. From the 8th to the 10th of that month aneroid readings showed a total elevation of 155 m. (510 feet) above the original height, giving, for the time interval of 100 days from the end of July to the commencement of November, an average rate of upheaval of 1·55 m. (5·1 feet) per day.

As in the case of the coastal belt, however, the full elevation of the summit of the New Mountain was not long maintained: aneroid determinations in April, 1911, showed a relapse of some 36 m. (120 feet).

Conclusion. Omori regards the upheaval of the New Mountain as due to the intrusion of magma; the explosions he ascribes to the gaseous emanations from this magma; and the earthquakes which preceded the explosions he connects with the formation of cracks and fractures below the surface permitting of the advance of the molten material. The situation of the craterlets outside the region of elevation is exactly what might be anticipated according to this interpretation, since the boundary fault of the new mountain is inclined outwards in 'normal' fashion. Altogether the Usu-san eruption furnishes a most suggestive picture of what one might expect at the surface during the injection of a laccolite accompanied by fracturing of the upheaved cover. At the same time without further knowledge of the underground relations of the various rock-masses, new and old, liquid and solid, it would be rash, however tempting, to dogmatize in this direction—even on the evidence so carefully observed and described by Dr. Omori.

It may seem ungracious to criticize where one is supplied with so rich a store of valuable information, but there is an omission to which attention may be directed, and that is the absence of any reference whatever to the petrology of Usu-san. It is certainly desirable that a comparison should be made between the material of the lava-domes O-usu and Ko-usu and that which has been intruded beneath the New Mountain; samples of the intrusion may reasonably be looked for in the ashes ejected at the numerous craterlets. In both cases the magma has given evidence of a rather unusually high degree of viscosity, and it would be interesting, if possible, to connect up this feature with some peculiarity of composition or condition as revealed by the microscope.

And now a point somewhat foreign to the main purpose of this discussion may briefly be referred to. Usu-san falls into line with Skye and Mull in furnishing an instance of peripheral upheaval in an igneous region. Although it is probable enough that the analogy thus afforded is a false one, it is nevertheless one that will have to be borne in mind by students who attempt an interpretation of the curved anticlinal folds so well developed in the case of the two Hebridean examples. Having broached the subject, it is only right to point out that the independence and isolation of the New Mountain of Usu-san is in striking contrast to the systematic grouping of the folds either of Skye or of Mull.

III.—The Green Keuper Basement Beds in Nottinghamshire and Lincolnshire.[1]

By Bernard Smith, M.A., F.G.S.

In the recent memoir on the *Geology of the Country around Ollerton*[2] a description is given of certain 'Green Beds' which in that neighbourhood form the base of the Keuper Waterstones and overlie the Bunter Pebble Beds.

The survey of the Nottinghamshire district being for the time completed, it seems desirable to lay more emphasis upon the occurrence of the Green Beds than has been possible in a sheet memoir.

Their chief importance lies in the fact that they are easily recognizable over a fairly large area and furnish engineers who may be boring for coal or water with a safe guide to the proximity of the surface of the Bunter Pebble Beds. By their aid also we are able to check certain published records in which the dividing line between Keuper and Bunter was perhaps not clearly recognized, and to prepare a contoured map showing the dip of the Bunter surface beneath some part of its overlying cover of younger rocks in Nottinghamshire and Lincolnshire.

In the Ollerton memoir the beds are described as follows:[3] "The greenish clayey basement beds of the Keuper were first noticed by W. T. Aveline, who, in 1861, drew attention to the 'alternations of

[1] With the permission of the Director of H.M. Geological Survey.
[2] Mem. Geol. Surv., 1911.
[3] Ibid., p. 26.

soft blue sandstone and blue clays' at the base of the Waterstones in this part of the county . . . They are 20 to 25 feet thick, and consist of micaceous ripple-marked pale clays, shales and sandy shale, of grey-green, grey-blue, or sometimes reddish tints, with occasional streaks of gritty sand, calcareous nodules in places, and obscure fragments of carbonized organic matter (probably plants)."

The greenish colour of the beds is most marked where they crop out at the surface; in borings the prevailing colour is a bluish-grey or grey. In many cases a thin calcareous conglomeratic sandstone underlies the Green Beds and rests directly upon Bunter sand-rock, but it is impersistent and may be altogether absent. It suggests some slight unconformity between Keuper and Bunter, which is also borne out by field mapping.

Outcrop. At the surface I have seen the beds as far south as Oxton (Sheet 126, N.S.), within 6 miles of Nottingham, and as far north as Retford (Sheet 101, N.S.). In all probability they could be traced further in both directions, for at Nottingham itself (Colwick Road, Sneinton, Sheet 126, N.S.) the lower Waterstones contain grey layers and overlie 3 feet of greenish-yellow flaggy sand-rock, which rests upon a thin conglomerate.[1]

Underground Extension. By means of borings they have been traced underground over a much larger area than their mapable outcrop would suggest, i.e. from Owthorpe (Vale of Belvoir, Sheet 142, N.S.) in the south, to beyond Gainsborough in the north and Lincoln in the east. From the records of some of these borings a table has been constructed (pp. 254–5) to show the persistence of the Green Beds, and the depth at which the Bunter Pebble-Beds occur in each case with respect to Ordnance Datum (see also Figure, p. 256).

In certain cases—marked by an asterisk (p. 254)—my reading of the records differs from the published account, the alteration depending as a rule on the occurrence of the Green Beds, which had been overlooked. The upper limits of the beds are often difficult to determine from the published records, chiefly because no attempt had been made to separate them from the more normal Waterstones above. Had it been possible to examine all the cores, the thicknesses given in the table would doubtless have shown less variability. At Owthorpe, Ruddington, Newark, Tuxford, and Southwell, at least, the figures quoted are probably too small, because layers of red marl sometimes occur with grey and blue layers at a higher level. The cores at Clipston and Rampton, which were personally examined, proved the blue-green facies to be fairly thick. At Markham Moor, about two miles north-west of Tuxford, a boring[2] (at Mr. Mudford's house) proved 30 feet of blue clay and stone resting upon red Bunter Sandstone (— 54 feet O.D.), from which water was obtained as soon as it was struck.

The Rampton (Criminal Lunatic Asylum) boring for water was of great interest because the normal Keuper Waterstones were remarkably like the Keuper Marls. The characteristic red sandstones were so

[1] *Geology of the Country between Newark and Nottingham* (Mem. Geol. Surv.), 1908, p. 37.

[2] Borers' record.

TABLE ILLUSTRATING THE DISTRIBUTION

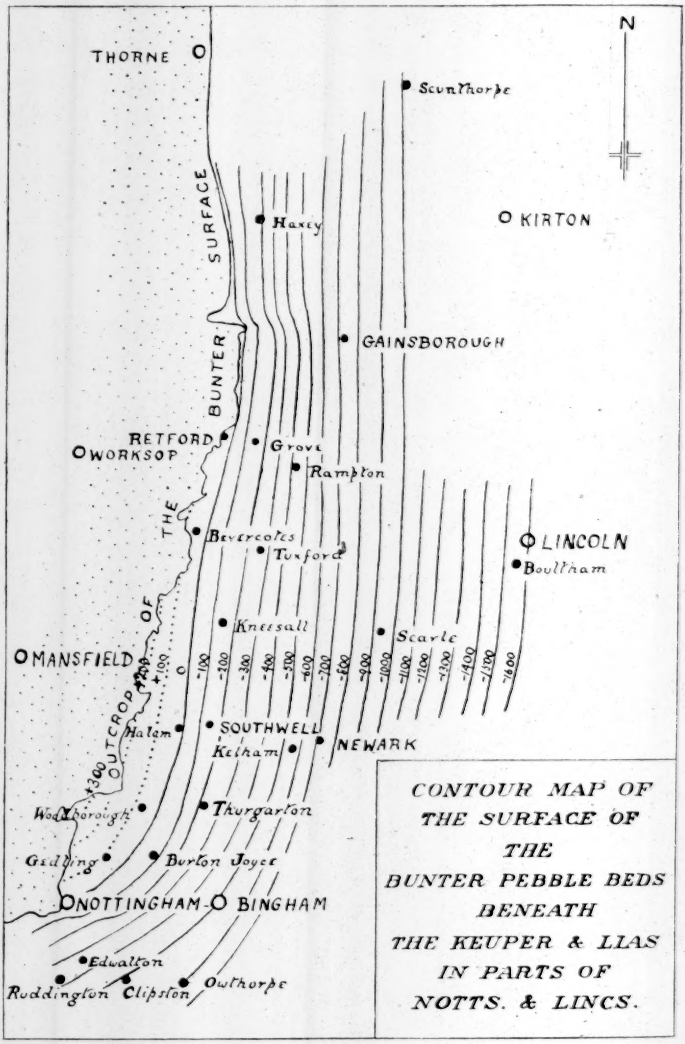
Locality.	1 inch Map.	Surface Level.	Level of Bunter Surface.	Thickness.	
				Waterstones Conglomerate.	Green Beds.
		Feet.	ft. in.	ft. in.	ft. in.
Owthorpe	142 N.S.	200	−601 6	—	22 6
Clipston	142 ,,	194	−518 0	A few pebbles	37 0
Ruddington	142 ,,	100	−386 8	3 0	21 3
Edwalton*	126 ,,	95	−334 5	0 6	11 3
Gedling (shaft)	126 ,,	185	+108 9	2 10	30 4
Burton Joyce	126 ,,	64	−90 0	2 6	14 0
Thurgarton	126 ,,	57	−210 7	2 8	24 6
Woodborough	126 ,,	116	+80 4	3 3	13 9
Newark	126 ,,	55	−713 0	1 6	25 6
Halam	113 ,,	120	—	2 3	18 0
Southwell	113 ,,	90	−163 10	Hard clay band	12 0
Tuxford	113 ,,	150	−263 0	—	29 0
Bevercotes	113 ,,	95	+57 6	—	18 7
Scarle	114 ,,	35	−923 0	—	12 0
Boultham* (Lincoln)	114 ,,	20	−1542 0	—	27 0
Rampton	101 ,,	110	−427 0	—	28 0
Grove	101 ,,	275	−152 0	—	42 0
Retford (Coal Co.)	101 ,,	50±	+8 0	—	30 6
Gainsborough	101 ,,	15±	−720 0	—	?
Haxey* (Idlestop or Southcar)	88 ,,	18	−119 7	—	45 0
Scunthorpe*	89 ,,	25	−1022 8	1 8	86 0
Crosby	89 ,,	14	−932 0	—	?

* See remarks, on p. 253, on these four localities distinguished by an asterisk.

AND DEVELOPMENT OF THE GREEN BEDS.

Description of 'Green Beds'.	Publication.
Bluish-grey rock.	*Geology of the Country between Newark and Nottingham* (Mem. Geol. Surv.), 1908, p. 107.
Alternations of red and grey sandstones, shales, shaly sandstones, and sandy shales, micaceous and sometimes ripple-marked.	MSS.
Red and grey sandy marl.	*Geology of the Country between Newark and Nottingham* (Mem. Geol. Surv.), 1908, p. 112.
Red and grey sandstone on grey conglomerate with pebbles.	Ibid., p. 100.
Red and grey marly rock.	Ibid., p. 102.
Marl mottled, pale pinkish and greyish, on loose brown sand.	Ibid., p. 99.
Blue marly sandstone, coarse grey sandstone, and red and blue sandy marl.	Ibid., p. 113.
Variegated marl and pebbles and soft sandstone.	Ibid., p. 117.
Blue marl, blue and red marl, sandstone, and cobbles.	Ibid., p. 105.
Blue and greenish clay.	MSS.
Light-blue clay.	*Geology of the Country around Ollerton* (Mem. Geol. Surv.), 1911, p. 78.
Blue sandy marl.	Ibid., p. 78.
Blue loamy sand with mica, red and blue sandy marl, red and shaly sandstone with mica.	Ibid., p. 73.
Specimens at 950 and 958 feet are hard white freestone (water-bearing) and hard grey shale.	*Geology of the Country around Lincoln* (Mem. Geol. Surv.), 1888, p. 194.
Hard grey marl with fine sand bands, grey marl with gypsum.	*Geology in the Field*, pt. iii, 1910, p. 491, and MSS.
Blue marl, blue clay, and red and blue micaceous ripple-marked shales, marls and sandstone.	MSS. and Home Office Record.
Soft and hard blue stone and clay.	MSS.
Red and grey marlstone, and grey pumice (? soft sandstone).	Rep. Brit. Assoc. for 1880, p. 104. *Geology of the Country around Lincoln* (Mem. Geol. Surv.), 1888, p. 97; and Proc. Yorks Geol. and Polytech. Soc., 1891–4, p. 25.
Red and blue marl with gypsum and veins of gypsum and beds of sandstone on 6 feet of red marl.	*Lincolnshire Water Supply* (Mem. Geol. Surv.), 1904, p. 108; and *The Eastern Extension of the Midland Coal-field* (Trans. Federated Institute of Mining Engineers), vol. xii, p. 518, 1896–7.
Red and blue sandy marl, beneath 8 ft. 6 in. red sandstone with grey joints and pieces of marl.	*Lincolnshire Water Supply* (Mem. Geol. Surv.), 1904, pp. 153–4.
Grey sandstones.	MSS.

poorly represented, and beds of marl so well developed, that it was found almost impossible to define where the marls passed into Waterstones. A division was made, however, upon other evidence. The Bunter Sandstone was of the usual type for the district, and contained pebbles as high up as the first 8 or 10 feet.



Details of the Lincoln (Boultham) boring for water were kindly supplied me by Mr. Henry Preston, F.G.S. The interpretation of this section becomes clear if we bear in mind the character of the

Rampton Beds. At Lincoln the Green Beds are well developed, but the lithology of the normal Waterstones is so similar to that of the Keuper Marls that they were thought to be absent. This led to the coarse red sandstone (some beds pebbly), below the Green Beds, being assigned to the Keuper Sandstones—as I think, quite erroneously. The fact that water was struck at 1,561 feet, and that no cores were then obtained until a depth of 1,577 feet was reached, also bears out my interpretation, for it frequently happens that there is a strong rush of Bunter water, which washes out the loose sandy top of the Pebble Beds, when the Green Beds are passed through in borings.

It has been stated[1] that in Lincolnshire the Triassic beds form one series "displaying modifications in texture, colour, and composition, which have no more than a local value; it is in some cases even difficult to decide where a boundary can be drawn between the Marls and the Sandstones, for beds of sandstone occur in the Marls and beds of marl in the Sandstones from top to bottom of the series". At Lincoln, however, the Green Beds represent a distinct horizon whose value has been shown to be of more than local importance, and one which is independent of whether the Waterstones are of the sandy or marly type.

In the Haxey (Southcar or Idlestop) boring for coal it is difficult to fix the base of the Keuper, but it probably occurs (on the evidence of the quantity of blue marl) somewhere near the level given in the table.

Interpreting the Scunthorpe section in the light afforded by those at Rampton and Lincoln, I should place the base of the Waterstones at 1,027 ft. 8 in. from the surface, throwing all the pebbly sandstone (the Waterstones in Notts are almost invariably free from pebbles, except in their basal conglomerate) below it (525 ft. 4 in.), and at present assigned to the Waterstones and Keuper Sandstone, into the Bunter, to which a thickness of only 196 ft. 11 in. is allotted. This classification receives confirmation from the succession determined by a boring near Crosby, situated a very short distance from the Scunthorpe site.

Conclusions. It will thus be seen that although the Green Beds, in the present state of our knowledge, do not form a very trustworthy guide to the underground position of the Bunter surface in the district north of Gainsborough, *they are to be depended upon* in the area which extends from that place as far south as the Vale of Belvoir, and as far east as Lincoln. They should therefore be of peculiar interest to all who may have occasion to probe the Pebble Beds beneath their overlying cover.

The *average* dip of the Bunter Pebble Beds determined from their contoured surface (see Map) is roughly 94 feet per mile, but near the outcrop the dip is slightly higher,[2] viz. 105 feet per mile.

[1] Professor P. F. Kendall, *Final Report of the Royal Commission on Coal Supplies*, pt. ix, p. 33.

[2] *Geology of the Country around Ollerton* (Mem. Geol. Surv.), 1911, p. 25.

IV.—Geological Notes on the Peninsula of Nicoya, Costa Rica.

By James Romanes, M.A., F.G.S.

Contents.

1. Introduction.
2. Limestones and Cherts.
3. The Igneous Rocks.
4. The Nicoyan Series.
5. Lithology of the Nicoyan Series.
6. Coastal Topography.
7. Summary and Conclusions.

1. Introduction.

During a visit to Costa Rica in the year 1910 I was able to spend about ten days in the comparatively little-known peninsula of Nicoya. The trend of the peninsula is north-west to south-east, and it is separated from the mainland by the Gulf of Nicoya, a shallow arm of the Pacific Ocean, which opens to the sea on the south-east.

The country is almost unmapped, and very little has hitherto been published as regards its geology, although Suess[1] makes special reference to it as a promising field for investigation. Sapper[2] traversed certain parts and records the occurrence of some rock-types, but gives no detailed description whatever. R. T. Hill,[3] in his paper on the Geological History of the Isthmus of Panama, mentions that Sjögren spent some time in Nicoya, and that his results are to be found in an appendix to the paper. No such appendix has, however, been published, and I have been unable to find any account of Nicoya by that author.

I spent some days in the village of Nicoya, which is situated almost in the centre of the peninsula, and then made a journey to the south, getting as far as the Rio de Ora. The area is one of high relief, and range after range of hills is encountered in travelling through it. In certain parts, however, there are broad tracts of level country from which the hills rise abruptly, and reference to this feature will be made in a subsequent part of the present paper. In some respects Nicoya shows close geological affinities with the adjacent portion of the mainland described by the present writer,[4] while in others it affords a striking contrast.

In such accounts as have been previously published there seems to exist a strong impression that older metamorphic rocks contribute largely to the formation of this portion of Costa Rica, but so far as my observations go this is entirely without foundation. It is only fair, however, to point out that this paper is the result of what really amounts to a single traverse from north to south, so that plenty of room remains for the existence of metamorphic rocks; yet throughout all the part with which I am acquainted the geology shows such

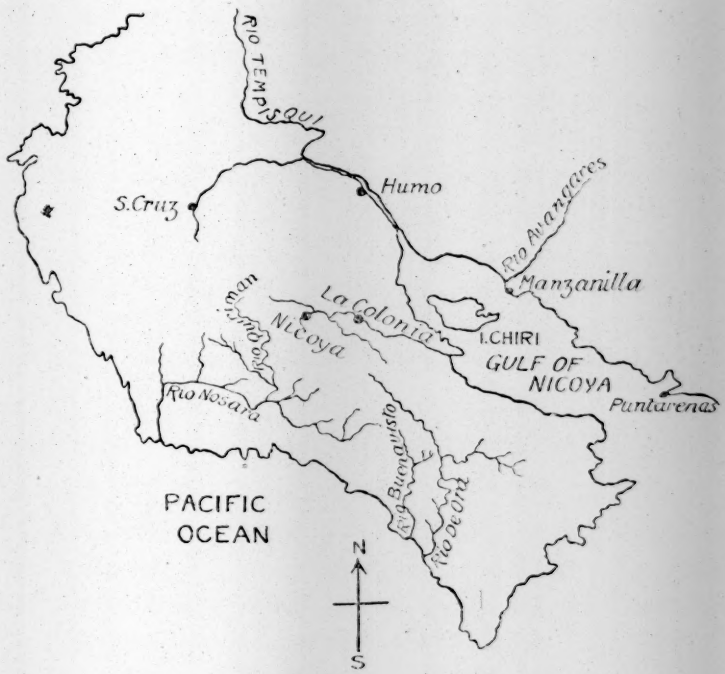
[1] *The Face of the Earth*, vol. iv, pt. v, p. 459.

[2] "Ueber Gebirgsbau und Boden des südlichen Mittelamerika": Peterm. Mitth. Erganzungsb., xxiii, No. 151, pp. 26–7, 1906.

[3] "The Geological History of the Isthmus of Panama and portions of Costa Rica": Bull. Mus. Comp. Zool. Harvard, vol. xxviii, p. 222, 1898.

[4] Quart. Journ. Geol. Soc., vol. lxviii, pp. 123–33, 1912.

marked uniformity that I am led to doubt the existence of any rocks differing much from those to be described.



Map of the Peninsula of Nicoya, Costa Rica.

The rocks met with may be divided into three groups as shown below, while in the second column are given the probable equivalents on the mainland.

Nicoya.	Mainland.
3. Nicoyan Series (marine ashes).	Manzanilla Series (? Miocene).
2. Igneous rocks, Teschenites, etc.	Limburgite of Manzanilla area. Monzonites of Cerro Candelaria.
1. Limestones and cherts.	Older limestones of Manzanilla area.

The order of succession given above seems to me the most probable; however, as no actual junctions were found direct evidence is not available, but as will be seen in the following pages there is considerable indirect evidence to support it.

2. Limestones and Cherts.

These are, I think, the oldest rocks exposed in the peninsula, and will probably be found eventually to have a wide distribution. The limestone is well seen about two miles north of the village of Nicoya, where it forms a conspicuous hill along the base of which runs the road to Humo. The rock is fine-grained and almost white, but with numerous joint-faces somewhat stained with iron. Chemical tests show that the limestone contains some magnesia. Little structure is seen under the microscope [9662],[1] as considerable recrystallization has taken place; there are, however, slight traces of organic structure which point to the rock having originally been a foraminiferal limestone. This limestone hill rises sharply from the very level ground which surrounds the village of Nicoya in precisely the same way as the hills of older limestone from the Manzanilla–Avangares peneplain of the mainland. This, coupled with the general similarity in appearance of the deposits, is strong evidence in favour of their belonging to the same series. I believe that many similar limestone hills are to be found, especially to the north in the neighbourhood of Humo; and as in places I have seen the rivers depositing calcareous sinter, limestone is apparently widespread.

The other deposits which I am inclined to include in this series are the Radiolarian cherts, although I quite admit that there is no direct evidence to show that they belong to the same period. These cherts I have only found in place in the upper part of the Rio Marote, i.e. north-west of the Humo road; but there, at least, splendid exposures are to be seen in the river bed over a considerable distance. Unfortunately the junction of the cherts with any other rocks is nowhere exposed. Lower down the stream, but separated by a considerable distance of river gravels, are exposures of the Nicoyan Series, while up stream I was unable to find any rock in place above the cherts. As will be seen from a subsequent part of this paper fragments of these Radiolarian deposits occur plentifully in the Nicoyan Series, which must therefore belong to a later period. The cherts are very hard and compact and vary from red to green in colour, and show much quartz veining on a minute scale. In thin slices [9663, 9664] these rocks are distinctly disappointing; they are evidently rich in Radiolaria, but none of the fine structures are preserved. They show an aggregate of cryptocrystalline silica the Radiolaria being represented by circles of clear microcrystalline quartz. A curious rock-type [9665] occurs plentifully in the Rio Nosara region which may also be of the some nature. It is of a rusty-brown colour with streaks and vesicles of soft iron oxides; the slice of this type certainly suggests affinities with the true cherts.

3. The Igneous Rocks.

Igneous rocks contribute very largely to the formation of Nicoya, and these form an extremely interesting branch of the geology. All the rocks which I was able to collect differ greatly in type from the

[1] The numbers in square brackets refer to slices in the Sedgwick Museum collection.

vast majority of those described from the mainland. Most of them are dolerites which often carry analcime; with them occur coarser and finer grained varieties, but all show a remarkably close genetic relationship; from this area I do not possess one single specimen of an andesite. This indicates that a sudden change has taken place in the comparatively short distance separating the mainland from the part of Nicoya which I visited. The dolerite series must have a wide distribution if we are to judge by the number of boulders brought down by all the rivers.

Time and the difficulties of travel prevented me from making any attempt at mapping even in the roughest way. One point, however, which seemed clear was that round the villages of Nicoya and La Colonia the igneous rocks came on in all cases exactly where the ground rose sharply from the raised peneplain of the Nicoyan Series. I will confine myself here to a description of the various types collected from different localities.

The finest-grained varieties are well exposed in the upper part of the Rio Pila, west of Nicoya village, and they continue westwards over the watershed down to the bottom of the next basin, which is drained by the Rio Quiriman. These rocks are much jointed and veined by calcite, and in the hand-specimen are very fine-grained and non-porphyritic, with a dark, almost black colour. Examined under the microscope [9666, 9667] they are seen to present some affinities with the variolitic basalts, although without a chemical analysis it is not easy to place them definitely. The dominant minerals are felspar and augite; the former is mainly labradorite, but with this occurs some orthoclase. The felspars have crystallized in long acicular crystals which often show plumose and stellate grouping. The augite builds small stout prisms which in the sections give it a granular appearance. Two kinds of interstitial matter are present; a dark-green glass with numerous rods and grains of magnetite, and a colourless isotropic substance of very low refractive index which seems to be analcime. This analcime is present both as interstitial patches and as strings and veins, showing that to a certain extent this mineral must be secondary, though much of it probably represents the final stages of crystallization at a low temperature and with concentration of mineralizing agents. Other zeolitic minerals with low double refraction sometimes replace the analcime, but all the chief characteristics of these finer-grained types recur in rocks with a very wide distribution. In addition to the locality referred to above I have collected similar rocks from the western coast of the peninsula in the Playa Corillo, a bay opening to the Pacific just south of the Rio Buenavista, from the gravels of that river and the Rio de Ora, and also from the watershed above Buenavista, at a height of over 2,000 feet. One or two of these examples [9668, 9669] are distinctly coarser in texture than the type described and appear to be in general holocrystalline and show a transition to the coarser varieties which are true dolerites and will now be described. They are best seen in the hills to the west of La Colonia, especially in the gorge of the Rio Lapa. The typical rock [9670, 9671] is even-textured, dark grey in colour, and consists of a medium-grained aggregate of felspar,

augite, analcime, and magnetite. The felspar is mainly labradorite in well-formed lath-shaped crystals. The augite is colourless to pale green, and is markedly granular. In all the slices examined there is a considerable quantity of green uralite derived from the augite. Analcime is generally present, either interstitially or in small secondary veins. In a few instances the occurrence of this mineral is curious, as it forms the central part of the felspar crystal, the boundary between the two being perfectly sharp, although very irregular. These dolerites are, I believe, also abundant, though probably not to the extent of the finer-grained varieties, and simply represent a deeper-seated phase of crystallization, both being derived from almost identical magmas. In a specimen [9672] from the gravel of one of the southern tributaries of the Rio Nosara the texture is somewhat coarser and the augite tends towards the subophitic habit.

One exceptional type [9673] remains to be described: the specimen was collected from a large boulder in the Rio Lapa where the rock probably occurs in place. It is much coarser than any of the foregoing varieties and approximates towards a plutonic habit. The plagioclase felspar is very decomposed, but is distinctly more acid than the usual labradorite, and builds large idiomorphic crystals; along with this is some orthoclase. The chief ferromagnesian mineral is a green augite with slight pleochroism, a variety lying between common augite and ægirine augite; secondary hornblende and magnetite are very abundant. The rock has a distinct resemblance to some of the monzonites of the Cerro Candelaria,[1] and these latter may quite easily represent an outlying part of the Nicoyan alkaline province.

4. The Nicoyan Series.

I have given this name to a group of marine sediments which occupy the lower ground in every part of the peninsula visited by me. These deposits while varying considerably in lithological character preserve, as a series, remarkable uniformity in widely separated localities. They are well exposed in many of the stream sections near the village of Nicoya, and form the flat expanse in which it is situated, but, as previously remarked, wherever the ground rises other rocks take their place. The section along the bed of the Rio Marote may be taken as typical. The deposits are always well bedded, and in the coarser varieties form beds 2 to 3 feet in thickness. They strongly resemble many of the Palæozoic greywackes of Britain. The finer types have the appearance of mudstones or shales. These alternating beds are considerably folded and occasionally dip almost vertically, although gentle anticlines and synclines are more generally developed; here and there some faulting has taken place. The strike of the series is very variable, but E. 30° N. is the normal. The same deposits are exposed further down the Rio Marote at La Colonia, and there again they occupy all the lower ground, but give way to igneous rocks in the surrounding high ground. The beds exposed in the river have a general strike of E. 35° S. with a vertical dip; they are, however, very much affected by minor contortions.

[1] Q.J.G.S., vol. lxviii, pp. 110–12.

To pass now to another part of the peninsula, the same sedimentary series is well exposed along the Pacific coast from the Rio Buenavista to the Rio de Ora. Here the topography is somewhat different as hills and valleys alternate without the broad plains which characterize the land to the north. The sediments extend inland for some distance, but to judge by the river gravels igneous rocks occupy most of the interior.

Buenavista Bay is bounded at either end by a bold rocky headland, and between these stretches a great curving beach of sand. The rock of the eastern headland is very fine-grained, grey in colour, hard and compact, with much calcite veining. The strike is E. 15° S. with a southerly dip of 65°. Similar rocks form the western limit of the bay, but the strike there is N. and S. with a very variable dip to the west. At Samara Point, some distance to the south, the deposits are much coarser in texture and show in hand-specimens numerous rock fragments; the strike is E. 20° S. with a southerly dip of 75°. The farthest south that I reached was the Rio de Ora, and here again this series is seen.

5. Lithology of the Nicoyan Series.

As previously stated these rocks show a very considerable range in texture and appearance; the coarser varieties closely resemble some of the beds of the Manzanilla Series, and are evidently marine volcanic ashes with, however, a considerable admixture of non-volcanic material. An example from the Rio Marote may be taken as typical of these. In the hand-specimen the rock has the general appearance of a coarse, compact, dark sandstone, with numerous slightly rounded rock fragments. Under the microscope this rock [9674] yields much valuable information. It is a slightly calcareous ash or fine breccia similar to that figured by the present writer from the mainland.[1]

Among the rock fragments are Radiolarian cherts identical with those to be found in place a short distance further up the valley. Limestone is present similar to the limestone exposed further to the north and described earlier in this paper. Together with these are fragments of a globigerine mudstone and small pieces of basic igneous rock, not unlike the variolitic basalts of the surrounding hills. The mineral particles consist of angular quartz, much fresh plagioclase, green hornblende and augite, with here and there a little glauconite. The cement is principally calcareous, but the amount present varies greatly in different examples. A specimen [9675] from the river bed at La Colonia is much finer in texture than the above, and contains scattered fragments of analcime. It is therefore, I think, a perfectly safe conclusion to consider the Nicoyan Series as having been laid down while the older limestones, cherts, and igneous rocks were being denuded and probably in many cases being broken up by outbursts of volcanic activity. In these deposits are preserved Rotaline Foraminifera, *Globigerina*, and fragments of the same *Orbitoides* that characterizes the Manzanilla Series, to which I have ascribed a probable Miocene age. The two series are therefore shown to be identical both lithologically and palæontologically.

[1] Q.J.G.S., vol. lxviii, pl. ix, fig. 4, 1912.

Passing southward to the Pacific Coast about Buenavista Bay we have on the one hand types [9676, 9677] distinctly coarser than that described above, while on the other are fine pale marls. The chief mineralogical difference between the former and that described from the Rio Marote are: (1) the almost complete absence of quartz and Radiolarian chert as constituents; (2) the presence of numerous fragments of andesites. The latter is a point of interest, since I noticed a complete absence of these rocks throughout my journey in Nicoya, a very striking difference from the mainland of Costa Rica, where they are by far the most prevalent rock-type. Interstratified with these normal marine ashes are found much finer deposits [9678], which merit description. They present a very fine-grained, compact appearance, and are most commonly of a grey or cream colour, showing a considerable amount of recrystallized calcite. They are very extensively developed in the cliffs at either end of Buenavista Bay. In a thin slice they are at once seen to present close similarity to globigerine ooze. The rock is largely calcareous and treated with dilute acid is reduced to a paste probably composed of volcanic dust. *Globigerina* is abundant, and the shells are infilled either by crystalline calcite or phosphate; the latter is pale brown in thin slices and corresponds to the mode of infilling described by Sir John Murray.[1] A beautiful example of this type [9679] outcrops on the north bank of the Rio de Ora, about 1½ miles from the sea. The rock is somewhat darker than usual, but under the microscope is seen to consist largely of *Globigerina* and presents a striking resemblance to the Chalk Rock of this country. These globigerine mudstones alternate quite abruptly with the volcanic ashes and must represent the sedimentation during periods of quiescence.

6. Coastal Topography.

The coastal topography of Nicoya corresponds exactly with the description of the north-east shore of the Gulf of Nicoya, which I have already published.[2] The inland ridges run out to sea as headlands, and between these are sweeping sandy bays. Buenavista Bay is a pretty example of this. The sand is thrown up into a distinct storm beach which has tended to pond back the river, with the result that much alluvium is being deposited behind the barrier. As on the mainland, large tracts of dark alluvial soil are to be seen, which represent completely silted-up bays, so that while the main coastal outline has been determined by a comparatively recent submergence it has been extensively modified by the deposition of alluvium. Near Humo very large flat tracts of this nature are to be seen.

7. Summary and Conclusions.

The formations met with are divided into three well-marked series:

(*c*) The Nicoyan Series.
(*b*) The igneous rocks.
(*a*) The limestones and cherts.

[1] Report of the scientific results of the exploring voyage of H.M.S. *Challenger*, 1873–6, Deep-sea Deposits, p. 393.
[2] Loc. cit., pp. 131–3.

The first and third of these seem undoubtedly to be represented on the mainland by the older limestones and Manzanilla Series respectively, and thus in the main Nicoya must be regarded as a westward extension of the coastal belt of the mainland, and not as has sometimes been hinted at, as a fragment of some older land mass. The extensive area of flat ground round the villages of Nicoya and La Colonia, which is again seen further to the north, I regard as a prolongation of the raised peneplain which forms the country between Manzanilla and Avangares on the mainland. With regard to the igneous rocks, they undoubtedly belong to an entirely different province from those of the rest of Costa Rica, with the possible exception of the Manzanilla limburgite and the monzonites of the Cerro Candelaria, both of which are more closely related to the Nicoyan series of teschenites than to the pyroxene andesites of the mainland. As regards the age of these alkaline rocks, I am inclined for the present to regard them as intrusive into the older limestones or sediments belonging to the same group, but the relationship of the different rocks is, I suspect, much complicated by faulted junctions.

V.—The Viscosity of Ice.

By R. M. Deeley, M.Inst.C.E., F.G.S.

With a view to showing that distortion under stress may take place in ice when several degrees below the freezing-point, Dr. Main [1] made a number of experiments at St. Moritz in the Engadine during the winter of 1887. Although, as Main says, "The experiments are to be regarded rather as proving the existence of continuous extension under tensile stress than as determining its amount," the records of his tests are sufficiently detailed to admit of the viscosity being calculated.

The tests were all made with the temperature below the freezing-point. He recorded the temperatures at the time extension readings were taken, and in some instances states the range of temperature between observations; but his records do not enable the true mean temperature to be ascertained, for during the nights the temperatures were lower than during the days. On this account the results cannot, except in a somewhat rough manner, be used to ascertain the variation of viscosity with temperature.

These experiments are of particular interest as Kelvin [2] used them in a paper read before the Geological Society of Glasgow in 1888. He says: "Main's experiments gave perfectly definite results though differing considerably with temperature." Adopting a viscosity obtained from Main's experiments, Kelvin comes to certain conclusions with regard to the possible thickness of floating ice fed by snow falling upon it, and also the probable thickness of an ice-sheet on land

[1] Proc. Roy. Soc., vol. xlii, p. 491, 1887.
[2] *Popular Lectures and Addresses*, vol. ii, p. 319.

fed by snow falling evenly over its surface. Recent exploration has shown that Kelvin's conclusions are not very wide of the mark. He does not, however, give any detailed figures, and we are therefore in the dark concerning the figure he took for the viscosity of glacier ice. I have recalculated the mean hourly extensions given by Main, as he had done this somewhat roughly, and in some instances had misplaced the decimal points.

The samples of ice tested were cylindrical, having been formed by freezing water in a metallic mould. In experiment No. 1, Table I, the water was not freed from air, and the test bar contained minute bubbles radiating in horizontal straight lines from the axis of the cylinder. In experiments Nos. 2 and 3 the water was first frozen, then boiled and refrozen in the mould, and only a core of minute bubbles up the centre of the cylinder remained.

The ice was secured in conical holders, and the extension was measured on lengths of from 216 to 244 mm. To prevent rapid changes of temperature the tests were made in two wooden boxes. That the temperatures read are correct is probable, for the thermometer was tested at Kew.

TABLE I.

Experiment No. 1.

A.	B.	C.	D.	E.	F.	G.	H.
Feb. 8 ...	12·5	−3·7		235·12		2·7	
			−3·6° C.		2·68		$27·83 \times 10^{12}$
,, 9 ...	12·0	−3·5		235·75		,,	
			−3·9		2·33		32·10 ,,
,, 10 ...	12·0	−4·3		236·31		,,	
			−3·9		3·04		24·66 ,,
,, 11 ...	12·0	−3·5		237·04		,,	
			−2·9		4·08		18·43 ,,
,, 12 ...	12·5	−2·3		238·15		,,	
			−2·25		6·50		11·43 ,,
,, 13 ...	11·5	−2·2		239·65		,,	
			−3·4		4·41		17·23 ,,
,, 14 ...	12·0	−4·6		240·73		,,	
			−5·1		5·30		13·40 ,,
,, 15 ...	11·0	−5·6		241·95		4·16	
			−4·9		6·70		15·86 ,,
,, ,, ...	14·0	−4·2		242·15		,,	
			−3·65		5·60		21·13 ,,
,, ,, ...	16·5	−3·1		242·29		,,	
			−3·1		9·50		12·46 ,,
,, ,, ...	18·5	−3·1		242·48		,,	
			−3·8		6·75		14·23 ,,
,, ,, ...	22·5	−4·5		242·75		,,	
			−5·25		7·18		16·53 ,,
,, 16 ...	8·25			243·45		4·3	
					4·00		30·70 ,,
,, ,, ...	10·0	Below −6° C.	Below −6° C.	243·52		,,	
					4·88		25·17 ,,
,, ,, ...	12·25			243·63		,,	
					3·60		34·83 ,,
,, 17 ...	11			244·45			

Experiment No. 2.

A.	B.	C.	D.	E.	F.	G.	H.
Feb. 19 ...	16·5	− 4·2		236·20		2·08	
			− 3·85		3·27		17·96 × 10^{12}
,, ,, ...	22·0	− 3·5		236·38		,,	
			− 3·15		3·00		19·60 ,,
,, 20 ...	10·0	− 2·8		236·74		2·1	
			− 2·5		2·22		26·80 ,,
,, ,, ...	14·5	− 2·2		236·84		,,	
			− 4·1		0·42		141·76 ,,
,, 21 ...	12·0			236·93		2·2	
					0·54		117·83 ,,
,, 22 ...	12·0	Below − 6° C.	Below − 6° C.	237·06		2·3	
					0·34		186·13 ,,
,, 23 ...	11·5			237·14			

Experiment No. 3.

,, 27 ...	14·0	− 2·8		216·20		1·9	
			− 3·25		1·80		27·30 ,,
,, 28 ...	11·5	− 3·7		216·59		,,	
			− 3·75		1·77		27·83 ,,
Mar. 1 ...	10·0	− 3·8		216·99		1·95	
			− 2·25		2·22		22·80 ,,
,, ,, ...	19·0	− 0·7		217·19		,,	
			− 2·35		0·96		52·80 ,,
,, 2 ...	9·5	− 4·0		217·33		2·0	
			− 2·30		1·06		49·10 ,,
,, ,, ...	17·0	− 0·6		217·41			

A, day; B, hour of day; C, temperature at time of observation; D, mean temperature; E, length of test bar in millimetres; F, mean hourly extension in hundredths of a millimetre; G, stress in kilos. per square centimetre; H, viscosity.

Defining the 'coefficient' of viscous traction as

$$\lambda = \frac{f}{\frac{dv}{dx}}$$

when λ is the coefficient, f the force (tractive or tensile) per unit area, and v the velocity at any point x, we have, for cases where the applied force f is so great in comparison with the weight of the bar that the latter may be neglected

$$\lambda = f\frac{v}{x}$$

where v is the rate of extension of a rod of length x.

It has been shown by Trouton that 'the coefficient of viscosity' is equal to one-third of the 'coefficient of viscous traction'.[1]

Applying the above to the first experiment of Dr. Main, given in Table I, we have

$$f = 2{\cdot}7 \text{ kilos per cm.}^2$$
$$= 2700 \times 980{\cdot}5 \text{ dyn. per cm.}^2$$
$$x = 235 \text{ mm.}$$
$$v = 0{\cdot}0268 \text{ mm. per hour.}$$
$$= 0{\cdot}0268 \div 60^2 \text{ mm. per sec.}$$
$$\therefore \lambda = \frac{2700 \times 980{\cdot}5 \times 235 \times 60^2}{0{\cdot}0268}$$
$$= 83{\cdot}5 \times 10^{12}$$

[1] Proc. Roy. Soc., A, vol. lxxvii.

and the coefficient of viscosity η is one-third of this

$$= 27{\cdot}83 \times 10^{12}.$$

Owing to the unfortunate uncertainty of the mean temperatures at which Main's experiments were made, a perfectly satisfactory comparison cannot be made of the viscosities in Table I.

On the Diagram, however, have been plotted the viscosities calculated from Main's figures. They show, but not very regularly, an increasing viscosity with falling temperature. The curve gives about the mean values of his results; but probably gives too high a viscosity, as his temperatures were taken during the day and may have been lower during the night. From the curve on this diagram the viscosity at 0·0° C. would appear to be about 6×10^{12}.

I have already attempted to ascertain the viscosity of some of the Swiss glaciers from their thickness, slope, and rate of flow.[1] The results obtained are given in Table II.

TABLE II.

Mer de Glace.		Morteratsch.	
At Trilaporte . .	$29{\cdot}48 \times 10^{12}$	High up . .	$292{\cdot}2 \times 10^{12}$
At Les Ponts . .	$27{\cdot}51 \times 10^{12}$	Middle . .	$143{\cdot}4 \times 10^{12}$
Above Montauvert .	$27{\cdot}64 \times 10^{12}$	Near end . .	$92{\cdot}31 \times 10^{12}$
Below Montauvert .	$24{\cdot}16 \times 10^{12}$		

Great Aletsch.	Lower Grindelwald.
$162{\cdot}2 \times 10^{12}$	$3{\cdot}274 \times 10^{12}$

Mr. Connell found that ice crystals sheared readily without fracture in a direction at right angles to the optic axes. From his experiments I calculated that the viscosity in this direction was only 2×10^{10}.[2]

Main's experiments, we have seen, were made with artificially frozen ice. Ice frozen in a metal mould is generally fine-grained, the mass consisting of needles of ice radiating from the centre to the sides. In such cases the optic axes of the crystals would be at right angles to the direction of flow, and the shear which ice can undergo at right angles to the optic axis would not assist the bar to lengthen very appreciably, even though the viscosity of ice in this direction be as low as 2×10^{10}. This arrangement of the individual crystals would tend to give a high value to the viscosity of the ice Main used; but the smallness of the crystal grains or needles would perhaps have a greater tendency to make it low.

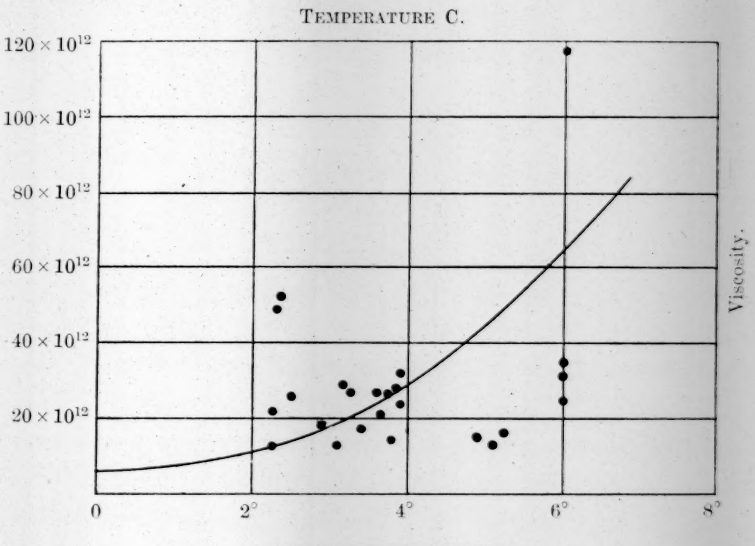
Glacier ice, unlike the frozen ice Main used, consists of crystalline granules, varying from the size of a pea to that of a walnut, or even larger. The optic axes are also at all angles, and the ease with which shear takes place at right angles to this axis no doubt tends to lower the viscosity of the mass.

All things considered it would seem that the ice tested by Main had a somewhat lower viscosity than glacier ice. For the viscosity at 0° C. we get from the Diagram 6×10^{12}, whereas the calculations I made from glacier ice led me to take 125×10^{12} as a mean, or about twenty-one times as great as those given by Main's experiments.

[1] Proc. Roy. Soc., A, vol. lxxxi, p. 250, 1908.
[2] Ibid., p. 256.

The probability therefore is that the figure for the viscosity of glacier ice taken by Kelvin was somewhat too low; but, as the volume of ice passed is proportional to the cube of the thickness of the glacier, even if Kelvin used 6×10^{12} for the viscosity, the thickness of the glaciers as calculated by him would only be too small in the proportion of 1 to $\sqrt[3]{21}$ or about 1 to 2·76.

I am indebted to Mr. P. H. Parr for some suggestions with regard to calculations of Main's experimental results.



REVIEWS.

I.—Evolution in the Past. By Henry R. Knipe, F.L.S. 4to, 10 by 7½ inches; pp. xvi, 242, with 56 full-page plates and 4 text-figures. London: Herbert & Daniel, 1912. Price 12*s.* 6*d.* net.

THE above is the title of a new work published this year by the author of *Nebula to Man*, which appeared in 1905. Like its companion this volume is very fully illustrated by fifty-six full-page plates in black and white, fifty being the work of Miss Alice B. Woodward and six by Mr. Ernest Bucknall; but, unlike its predecessor, the present work is written in prose.

There is a small, but increasing, section of the reading public to whom the purely popular or the purely technical treatment of a subject alike give little satisfaction. And on some subjects, among which palæontology might perhaps be included, literature can hardly be found outside these two extremes; therefore a debt of gratitude is certainly owed to Mr. Knipe for so ably supplying a distinctly felt want.

Furthermore, to many people dry bones, even when exhumed after

the lapse of many ages, present little or no interest, but Mr. Knipe has given so lucid and realistic a representation of the appearance and life-history of the inhabitants of our globe in earlier times that he may be expected to make numerous converts to the belief that there is no more fascinating study than that of the earth's former inhabitants, including man himself, and one, moreover, in which many secrets remain to be unravelled and many mysteries yet await elucidation.

The book is well and clearly planned, a distinct necessity to ensure success for such a comprehensive undertaking; the author passes in review the successive phases of animal, and more briefly vegetable, life as it has appeared on the earth and is represented by the very earliest known remains until the present-day order of things had been reached. First of all a Chronology of the Earth is given, with a necessary footnote proclaiming that all dates are conjectural though based on the thickness of the various strata, and these will no doubt appeal to many readers who like to reduce all things to terms applicable to the personal life of to-day. This is followed by an introduction giving a simple and brief review of the doctrine of evolution, and a chapter suggesting the probable conditions and manner in which the earliest forms of life appeared on the earth during the 'foundational ages'.

The succeeding sixteen chapters of varying length are each devoted to the description of the inhabitants of the earth during each of the similar number of periods from the Cambrian to that of the present day. The various phases and predominant forms of different epochs are passed in review and provide a clear picture of their several stages and the gradual transformation of the fauna, from the days when invertebrates held unchallenged sway until the time came when Man through his gradually awakening intelligence acquired power for good or evil over all other creatures of land or sea. That man's rise in power has been accompanied by a corresponding decline in the fortunes of mammals of less highly developed brain power is undoubted, and on p. 114 the author draws a pathetic picture of these failing fortunes when he says, "This decline commenced probably in the Pliocene Period, was accelerated in the Pleistocene, and has continued ever since. To-day, brute life, except in a domesticated condition, is at a very low ebb. This long continued downward course is doubtless in part ascribable to climatic changes and disease; but in its later stages it has beyond question been brought about by man."

The numerous full-page plates portraying dominant and peculiar forms, the fossil remains of which have been discovered in deposits of the various periods, form an invaluable complement to the letterpress. These restorations have been prepared with the greatest care and are as reliable as the available material renders possible, and convey a sufficiently accurate impression of the appearance of these extinct species. Five of these plates have already appeared in *Nebula to Man*, but the remaining fifty-one have been specially drawn for this work. Six by Mr. Bucknall show prevailing forms of vegetation which, playing such an important part in the making of scenery, are helpful

in giving an impression of the landscapes of different epochs. Miss Woodward's drawings are among the best we have seen of restorations of long extinct forms, for, while faithful to the evidence of structure afforded by the remains discovered, she has exercised an admirable restraint which has enabled her to avoid the tendency, so often seen in the rendering of such subjects, to portray the creatures of the past like nothing more than the grotesques of a fantastic nightmare. At the same time she has succeeded in giving spirited representations of various forms of life ranging from the graceful stone lily to Mousterian man. Where so many show such high merit, it may seem invidious to make a selection for special notice; but among those particularly conveying the feeling of wild life in unrestricted freedom might be cited the plates portraying *Hesperornis* and *Archæopteryx* among the birds, *Mæritherium*, *Machærodus*, *Hipparion*, and the later *Hippidium* of the mammalia; while particular mention may also be made of the plates showing Devonian sharks and Ganoids, Ichthyosaurs preying on Belemnites, and the Jurassic *Diplodocus Carnegiei*.

Considering that so frequent use has to be made of scientific names, the text is singularly free from small clerical errors, though a few may be noticed, such as the two spellings given on opposite pages of the generic name of the 'giraffe-camel' from the Miocene of Colorado.

In his preface Mr. Knipe very generously and rightly acknowledges the valuable assistance received from members of the staff of the British Museum (Natural History) and other specialists, more particularly with reference to the pictured restorations which form such a valuable adjunct to the letterpress. The volume is furnished with a good index and a very useful list of authorities consulted. When preparing this work for a second edition it might be suggested that a few sketch-maps indicating the extent of the earth's land surfaces during different periods might still further add to its completeness.

On nearly every page are marginal headings, if one may be permitted the use of such a term, which will be found of great assistance when employing this as a work of reference.

We sincerely hope that the volume under review will eventually have to be referred to as one of Mr. Knipe's 'earlier works', and it is in anticipation of its successors that it may be well to suggest to the author that, while technical language is necessarily to be avoided, a tendency to err in the opposite extreme is to be deprecated on the ground that, while more intelligible, it is perhaps even more aggravating to the reader. As an example taken at random, we may mention his reference to 'Trunky life' in India in early Pliocene times; the 'elephants' in the margin is illuminating; nevertheless one is left with the impression that this is hardly the expression best suited for the occasion, and that one would be similarly affected if in reading a History of England, for instance, the author were to refer to Alfred the Great as 'Alf'.

In conclusion, it may be said that this handsome volume is well got up and printed on good paper, which is satisfactory to note when

the many illustrations are necessarily reproduced on a heavier make with a smooth surface; and it may be safely recommended to those interested in palæontology and to whom scattered scientific papers may not be available, as a thoroughly up-to-date and agreeable outline of the subject.

II.—Prehistoric Man. By W. L. H. Duckworth, M.A., M.D., Sc.D., University Lecturer in Physical Anthropology, Cambridge. 8vo; pp. 150. Cambridge: University Press, 1912. Price 1*s.* net.

THE *Antiquity of Man* was written by Sir Charles Lyell just half a century ago, and marked an epoch in the study of the early human race; it gave an impetus to and an interest in that subject which have only increased as time has run on, and were never greater than at the present moment. During much of that time the interest centred chiefly around the ancient stone implements which from their indestructible nature have been found in surprising numbers, not only in this country and on the continent of Europe, but in every quarter of the world. The remains of man himself from the deposits where his handiwork has been so abundant have been comparatively few. Indeed, considering the enormous number of animals' bones obtained from Pleistocene deposits, it is remarkable that those of man should have been so seldom recorded. However, during the last ten or fifteen years some most interesting discoveries have been made, and it is chiefly these which are dealt with in the present volume. It is very fitting that the jubilee of *The Antiquity of Man* should be marked by the publication of this admirable little book by a master of anthropology, which will certainly serve many students as an introduction to the study of 'prehistoric Man'.

Limited space (150 pages) has not permitted the author to do more than give a general view of the subject, but he has contrived to condense in that space a large amount of information in a somewhat novel and interesting form. It is reassuring at the outset to find that Dr. Duckworth refuses to give "dates in years to the several divisions of time now recognized", and our faith in his judgment in other parts of his book is thereby strengthened.

In the first place the author reviews the various well-authenticated discoveries of human remains in Pleistocene and earlier deposits during the last fifteen years. And we may here say how much we should have liked to have had a somewhat full account of the peculiarities of the Spy skeletons which have served as a foundation for the characters of the Neanderthal race.

A novel method of comparing these remains is adopted. Disregarding, for the time, the horizons from which the skeletons have been obtained, these have been grouped according to their greater or less resemblance to the bones of modern men; and this emphasizes some peculiar points. In the *first* group are included *Pithecanthropus* and the Heidelberg jaw, these forming two divisions of a group far removed from modern man, and at the same time occurring in far-off *pre*-Palæolithic deposits. A *second* group includes Palæolithic and modern men; but these are put in two divisions—(*A*) The Neanderthal (or La Chapelle) race; and

(*B*) Modern men and certain fossil remains which can hardly be separated from them, such as the Engis skull and the Galley Hill skeleton. If it be accepted that the Galley Hill man is thus closely allied to modern men, then, as the Galley Hill skeleton was found in deposits much older than those yielding the remains of the Neanderthal race, we have to account for the more modern type being in the older deposit.

In subsequent chapters are considered the relation of these fossil human remains to the deposits in which they are found and to the mammalia and flint implements with which they are associated. Then follows an account of the attempts which have been made to divide the Pleistocene deposits and of the Glacial and Interglacial arrangements which have been suggested. Finally, Dr. Duckworth traces the possible lines of the evolution of man.

Throughout the book the author has striven to give a general account of the various phases of the study of prehistoric Man rather than to express definite opinions on any of the thorny problems with which the subject is beset. There is a capital bibliography, however, which will enable the student to consult the original authorities for himself and, it may be, draw his own definite conclusions.

E. T. N.

III.—Geology of the Federated Malay States.—We have received from Mr. J. B. Scrivenor, Geologist to the Government of these States, an account of *The Geology and Mining Industries of Ulu Pahang, with a sketch map showing the geological structure of the country* (1911).[1] The geological map is the first, so far as we know, that has been published, of any part of the States. It is on the scale of 8 miles to 1 inch, is clearly printed in colours, and the topography has mostly been surveyed by Mr. Scrivenor. The formations include—(1) The *Raub Series*, limestones and shales with fossils of Carboniferous and Permian. (2) The *Chert Series*, consisting of black and coloured cherts with abundant Radiolaria, jasper, and siliceous shale, also with a few Radiolaria: in one locality there was a thin seam of Radiolarian chert between a flow of lava and an underlying bed of ash; fragments of chert occurred in the lava, but the relations between the Chert Series and other formations have not been clearly determined. (3) The *Gondwana rocks*, comprising conglomerate, quartzite, sandstone, grit, shale, and clay-slate: fossils from the sandstones include several species of *Myophoria* and *Chlamys valoniensis* (characteristic of Rhætic), so that the strata are referred by Mr. R. B. Newton to the uppermost Trias; a species of *Semionotus* has also been identified by Dr. A. Smith Woodward; pebbles of chert resembling the rock of the Chert Series occur abundantly, and suggest unconformity between the Gondwana and Chert Series. (4) The *Pahang Volcanic Series*, consisting of lavas and ashes and some deep-seated rocks, a group that appears to be associated more or less with all the three preceding groups, and to be older than (5) the *Granite* of the Main Range.

[1] On sale at the Malay States Information Agency, 88 Cannon Street, E.C. Price 3*s*. 6*d*.

The author describes some of the igneous rocks, granophyre, andesite, dacite, dolerite, etc. He comments on the association of Radiolarian chert and lava, and on the views expressed on the subject by Mr. H. Dewey & Dr. J. S. Flett.[1] The newest rocks, apart from Alluvium, are small dykes of dolerite which cut the granite, and are almost certainly of Tertiary age.

With regard to the mining, gold has been obtained from alluvial deposits and from weathered rocks in sufficient quantity to repay a Malay, but not a white miner "unless he chose to live like a Malay". Two mines are still being worked in lodes in the Raub Series. The greater part of Ulu Pahang produces no tin-ore, and the author fears it never will be obtained in any part in large quantities.

Mr. Scrivenor has also published *Notes on prospecting for Tin-ore in the Federated Malay States* (Kuala Lumpur, 1911).

IV.—Geological Survey of New Zealand.—Bulletin No. 13 (New Series), issued by the Department of Mines, consists of a memoir on *The Geology of the Greymouth Subdivision, North Westland*, by Mr. Percy G. Morgan (Wellington, 1911, pp. 159). This work is illustrated by four detailed geological maps and three sections, together with special maps of the Kotuku Oilfield and Greymouth Coal-field, and sundry pictorial views and text-illustrations. The district lies on the western side of the southern island, and contains the following geological formations: *Palæozoic*, Greenland Series, composed of argillites and grauwackes that may be of any age from Ordovician to Carboniferous; *Eocene*, Coal-measures; *Miocene*, Greymouth Series, mudstones, sandstones, limestones, and conglomerates; *Pliocene*, sandstones, lignite, and gravels; *Pleistocene*, glacial, fluviatile, and marine deposits; and *Recent*, fluviatile and marine gravels and sands. Igneous rocks include granite of an age newer than the Greenland Series and pre-Tertiary, and basic dykes that may be slightly younger than the granite.

The Greenland Series has yielded some metalliferous quartz-veins with gold and ores of antimony, but there has been little lode-mining: gold has been obtained in some abundance mainly in the Recent alluvial deposits, to some extent in Pleistocene deposits, and in small quantities in Pliocene and earlier Tertiary accumulations.

While mining is the chief industry, that of coal-mining is by far the most important; the output for 1910 was 466,661 tons, and the total amount of coal raised since 1890 is estimated at nearly six million tons. Considerable increase is anticipated in the output of coal. It is stated that favourable conditions for the occurrence of petroleum in quantity seem to exist, but until deeper trial-holes have been put down the matter cannot be settled. Notes are given of other mineral products, of building-stones, materials for brick-making, cement, etc. From an agricultural point of view there is little arable land, but much grass land suitable for cattle-grazing, good timber land, and some ground adapted for fruit-farming.

[1] Geol. Mag., 1911, pp. 202, 241.

V.—Geological Survey of the Transvaal.—In the volume of Annual Reports for 1910, part iv (1911), the Director, Mr. H. Kynaston, gives a general account of the field-work, with some important particulars relating to building-stones, illustrated by twelve pictorial views of quarries. Mr. E. T. Mellor contributes a Report on "The Geology of a portion of the Central Witwatersrand", with a map showing the structure of the area; another Report is on "The Geology of the Steelpoort River Valley, including the country round Roos Senekal and Dullstroom", by Mr. A. L. Hall, illustrated by views, sections, and a coloured geological map; a third Report is on "The Geology of the Rustenburg and Zeerust Bushveld south of the Dwarsberg", by Mr. W. A. Humphrey, and a fourth Report, by the same geologist, is on "The Transvaal System west of the Klip River Valley", both illustrated by coloured geological maps.

VI.—Yorkshire Geological Society.

SOME very interesting papers are contained in part iii (vol. xvii, n.s., 1911) of the Proceedings, issued in January last. The Presidential Address is printed herein, and in this Professor P. F. Kendall deals with the Progress of Geology, with special reference to Yorkshire, during the fifty-two years in which the Marquis of Ripon (his predecessor) was President of the Society. An important paper follows on "The Lower Oolites of Yorkshire", by Mr. L. Richardson. The succession of beds at Blea Wyke, Ravenscar, is given; but the *aalensis* and *moorei* beds (between which the division line between the Lias and Oolites is generally drawn) are absent at this locality. The Dogger is found to rest upon a deeply-eroded surface of the Lias, and hence the division line between the Lias and Oolites is usually sharply defined. The subdivisions of the Oolites are considered in detail, and the paper is illustrated by three fine photographs. Three appendices follow, two by Mr. S. S. Buckman on the Ammonites (one being a comparison of the Upper Toarcian Beds in Yorkshire and in the Cotteswolds), and the third by Mr. Talbot Paris on the Echinoids.

A beautifully illustrated paper is contributed by Mr. G. W. Lamplugh "On the Shelly Moraine of the Sefström Glacier and other Spitzbergen phenomena illustrative of British glacial conditions", an abstract of which was delivered at the Sheffield Meeting of the British Association, 1910 (Section C). The paper contains a note by Dr. A. Strahan and a list of shells by Professor Gerard de Geer.

Some interesting results of the careful collection and study of Chalk Belemnites are presented by Mr. J. W. Stather. A complete transition can be traced from *Actinocamax westphalicus* through *A. granulatus* to *A. quadratus*, and the forms show a deepening of the alveolar cavity as they are collected from successively higher Chalk. A convincing diagram accompanies the text, and this shows the actual depths of the alveolar cavities of a series of specimens collected from the Upper Chalk of Yorkshire, the exact measurements through 650 feet of Chalk being given with each specimen. These results were first obtained by M. de Grossouvre, and were confirmed by Dr. Rowe's researches in the South of England. In Yorkshire, however, Mr. Stather is the first to collect the complete series.

Dr. Albert Wilmore contributes a "Note on the Zones of the Carboniferous Limestone South of the Craven Fault", and Dr. Arthur Vaughan describes and figures *Clisiophyllum ingletonense*, n.sp., a form "with strong convergence towards *Carcinophyllum*, particularly in the young stages", and occurring in the basement beds (C_2–S_1) of Ingleton.

VII.—Liverpool Geological Society.—The last part of the Proceedings (vol. xi, pt. ii, session the fifty-second, 1910–11) contains a great deal about Triassic geology. Mr. W. Hewitt in his Presidential Address, gives a comprehensive account of the present state of our knowledge of the physical conditions under which the local Triassic rocks were formed. The various theories are discussed and the more important papers referred to, but, as Mr. Hewitt observes, the problem is still an open one. Footprints in the Trias form the subject of papers by Mr. H. C. Beasley and Mr. F. T. Maidwell. Mr. Beasley deals with the group of footprints found at Storeton in 1910, and from the new examples is able to write a fresh description of the 'G' (Chelonoid) forms. These Storeton 'G' prints are not webbed, but recently an undoubted example of webbing has been discovered among the Rhynchosauroid prints at Runcorn. Mr. F. T. Maidwell, in his "Notes on the Footprints from the Keuper of Runcorn Hill", describes several of the 'D' prints under the name *Rhynchosauroides*, and founds the new species *R. membranipes*. Some interesting observations on webbed prints and the significance of their occurrence in these rocks, are included in Mr. Maidwell's paper.

The finer materials of Triassic rocks have been examined by Messrs. C. B. Travis & W. H. Greenwood, who give their detailed results in a paper on the mineralogical and chemical constitution of the Triassic rocks at Wirral. These results are compared with those obtained by workers in other areas, and the conclusions are of some interest. The condition of the quartz tends to show that the bulk of the material of the Wirral Trias was derived from granitoid rocks, and a smaller proportion from sedimentary and volcanic rocks. The two varieties of tourmaline, brown and blue, are considered to come from different sources. On the whole, the authors think that the Wirral Trias cannot have been derived from the same source as that of the deposits of the Trias in South-West England and the Midlands.

The list of papers on the geology of the country around Liverpool which was started by the late Mr. G. H. Morton is continued in this part of the Proceedings to the year 1909, by Mr. W. Hewitt.

VIII.—Proceedings of the Cheltenham Natural Science Society for the Session 1910–11. N.S., vol. i, pt. v, November, 1911. Cheltenham: Norman, Sawyer & Co., Ltd. Price 1*s*.

THE useful account of "Brickearths, Pottery, and Brickmaking in Gloucestershire", by L. Richardson and R. J. Webb, concludes in this part of the Proceedings with details of the various tile-and brick-clays in the Coal-measures and in the Old Red Sandstone. The famous Cattybrook bricks are made from the Coal-measure clays of this county; and six localities are still worked, while eight are now

disused. The three localities from which the Old Red Sandstone supplied bricks are now disused.

This part contains, besides the Presidential Address (by Dr. E. T. Wilson) on "Our Inheritance", a short paper on "Stone Circles on the Blackhedge Estate", by Mr. L. Richardson, and a note by Dr. A. Smith Woodward on "*Euthynotus*: a Fossil Fish from the Upper Lias of Dumbleton, Glos."

IX.—Micropetrology for Beginners: an Introduction to the use of the Microscope in the examination of thin sections of Igneous Rocks. By J. E. Wynfield Rhodes, B.Sc. 8vo; pp. xv, 126, with 1 plate and 26 text-illustrations. London: Longmans, Green & Co., 1912. Price 2*s.* 6*d.* net.

THIS little book, introduced to the public in a preface by Mr. C. H. Sidebotham, F.G.S., will prove a useful primer for the student, and will no doubt be an aid to those going up for examination in petrology. The methods of preparing thin slices of rock and of identifying the minerals under the microscope, the composition of the principal rock-forming minerals and of the igneous rocks, including such forms as Laurvigite, Foyaite, Ditroite, Hyperite, Markfieldite, and Teschenite, are treated systematically and concisely. Finally, there is a glossarial index.

X.—The Voyage of the *Discovery*. By Captain Robert F. Scott, C.V.O., R.N. Re-issue, 2 vols. 8vo; pp. xiv, ix, 410, 387, with 12 plates and 2 maps. London: Smith, Elder & Co., 1912. Price 3*s.* 6*d.* each vol.

THIS work was originally published in two large octavo volumes in 1905. It has now been re-issued in smaller size and at a price which will be welcome to many geologists and students in different branches of science, as well as to a wide circle of other readers interested in this fascinating record of arduous and successful exploration. The text has been reproduced intact, with the summary of the geological observations by Mr. H. T. Ferrar, and the account of the whales, seals, and birds by Mr. E. A. Wilson. To the student of glacial phenomena the whole narrative is full of instruction on ice and ice-action, and the only regret felt will be in the fact that but few of the original illustrations have been reproduced.

XI.—Brief Notices.

1. Mineralogical Notes.—Under the title "Mineralogical Notes, Series 1", the United States Geological Survey has published Bulletin 490 (Washington, 1911), by Dr. Waldemar T. Schaller. This is a continuation of Bulletin 262 (1905), and contains the results of further research carried on by the author in the chemical laboratory of the Survey. Some of the papers were originally written and published in conjunction with members of the Survey; acknowledgment has been made to these, and some papers have been re-arranged. Among the minerals considered chemically, hulsite, paigeite, jamesonite,

and warrenite may be mentioned, and a few pages are devoted to the composition of molybdic ochre. Some new forms of calcite crystals are also described.

2. Fossil Beaver from California.—Publication 17 of the University of California (Bulletin of the Department of Geology) contains the description and figures of a tooth m. 2 of *Castor californicus*, n.sp., by Dr. Louise Kellogg. The specimen was found at the northern end of the Kettleman Hills, Fresco County, and is of Middle Etchegoin (late Miocene or early Pliocene) age, being therefore the earliest known true beaver from America. It is very similar in pattern to the teeth of various recent species of *Castor* found on the Pacific Coast, and is compared with *C. neglectus*, Schlosser.

3. Geology and Folk-lore. — An interesting essay entitled "'Snakestones' and Stone Thunderbolts as subjects for systematic investigation" has been communicated by Mr. Walter W. Skeat (*Folk-lore*, xxiii, p. 45, March, 1912). He has given many records of fossils used as charms or as medicinal cures, or connected with forms of worship. Thus, in India both celts and ammonites are connected with the worship of Vishnu.[1]

4. British Late-Glacial and Post-Glacial Deposits.—An essay by Mr. G. W. Lamplugh on this subject was brought before the International Geological Congress at Stockholm in 1910 (reprinted from the *Postglaziale Klimaveränderungen*). After expressing his conclusions "that there is no clear evidence for the supposed separate glaciations and warm inter-Glacial epochs, but on the other hand there is strong evidence that the main ice-sheets persisted throughout the Glacial period, and only their margins oscillated widely", he proceeds to discuss the field-evidence, which leads him to believe that the post-Glacial deposits were accumulated during progressive amelioration of climate.

REPORTS AND PROCEEDINGS.

Geological Society of London.

March 27, 1912.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The following communications were read :—

1. "The Glaciation of the Black Combe District (Cumberland)." By Bernard Smith, M.A., F.G.S.

After a brief discussion of previous work and literature, a short sketch is given of the geological structure of the district.

With the exception of the western coastal plain the main topographical features are pre-Glacial, but they have been either subdued or accentuated by glaciation. The chief pre-Glacial drainage-lines determined those of the present day.

Evidence is given to show that, during the flood-tide of glaciation, the whole district was swamped beneath an ice-sheet formed by the

[1] See also Dr. H. Woodward, "On Fossils applied as Charms or Ornaments": Geol. Mag., 1893, p. 246.

confluence of Lake District and Irish Sea ice, the summit of Black Combe (1,969 feet) being overridden by ice which was comparatively clean.

The Lake District ice travelled from the Broughton Valley, the Duddon Valley and high ground to the west, and from Eskdale. Near the coastline the overmastering pressure of the Irish Sea glacier diverted the seaward flow of the Lake District ice to the south or south-east.

The deposits of the Lake District ice are briefly described, and a more detailed description is given of the deposits of the Irish Sea ice which are exposed in the sea-cliffs of the coastal plain. The distribution of Scottish boulders is also discussed.

In the Lower Boulder-clay of the westward mountain slopes (the ground-moraine of combined Lake District and Irish Sea ice) there is evidence both of the interweaving of drifts of distant and strictly local origin, and of a certain amount of movement of ice inland.

Phenomena which occurred during the withdrawal of the ice are next described under the following heads:—

(1) *Moraines and trails of boulders.*

(2) *Marginal channels and associated sands and gravels.*—The trend of these channels is, in the best examples, parallel to the coast and nearly at right angles to the present drainage-lines. In some cases the channels were carriers of the ordinary marginal drainage of the ice-sheet, in other cases they were cut by overflow waters from impounded lakelets. Before the cutting of the channels between Eskdale and Bootle the ice overrode a series of sands and gravels formed, chiefly as a marginal outwash-fan, at a slightly earlier date.

(3) *Sand and gravel of the plain.*—These deposits are considered to have been accumulated after the formation of the channels near Bootle, the material being in the main deposited in embayments of the margin of the Irish Sea ice.

(4) *The Whicham Valley and Duddon Estuary Lakes.*—Sand and gravel was also accumulated at the extremities of ice-lobes which were thrust into the mouths of valleys, so that the normal drainage of these valleys was obstructed. The ice-dammed Whicham Valley Lake is described in detail; it drained at first into the Duddon Estuary by the Gill Scar channel, but afterwards through the obstructing barrier—reversing the flow of water.

The Upper Boulder-clay is then briefly discussed, and some account is given of late corrie glaciation.

In conclusion, certain hanging valleys are shown to be due to the over-steepening of hill-slopes, or over-deepening of main valleys during the maximum glaciation.

2. "The Older Palæozoic Succession of the Duddon Estuary." By John Frederick Norman Green, B.A., F.G.S.

The Lower Palæozoic geology of the estuary of the Duddon, which separates Cumberland and Lancashire, has been little studied, but is of especial interest, because the (?) Skiddaw Slate, Volcanic Series, and Coniston Limestone Series are in proximity along an outcrop

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of several miles, and the alteration is generally less than in other parts of the Lake District. The following succession is described in descending order:—

	Thickness in feet.	
Limestones (Sleddale Group)	100	
Stile End Beds	40	
(unconformity)		
Upper Tuffs	40	Volcanic group, 650 feet.
Rhyolites	60	
Harrath Tuffs	100	
Middle Tuffs	300	
Dog Crag Tuffs	50	
Mottled shale	100	
Blue shale or (?) Skiddaw Slate—no base seen.		

The blue shale and mottled shale are described; and it is shown that the latter is identical with the former, except for the addition of lapilli of andesite-glass and slate. Tuff-free bands, indistinguishable from blue shale, are intercalated. Conformity is also proved by mapping and by sections exposing the junction.

The Dog Crag type is of the same material as the mottled shale, but with little muddy matrix, and passes up into the bedded Middle Tuffs, composed of fine-grained debris; these in turn pass up into the Harrath type, marked by fragments of variolite, and, in the upper part, felsite. The rhyolites are considered to be substantially contemporaneous. The thin andesitic Upper Tuffs are only seen in the neighbourhood of Millom.

The pyroxene-andesites of the district are briefly described. They vary from acid forms with oligoclase in the ground-mass and felspar-phenocrysts, to forms with an andesine-augite matrix and augite-phenocrysts. They occur sporadically in any horizon from the Skiddaw Slate to the rhyolites, and in many cases are certainly intrusive. The sills metamorphose the Middle Tuffs near their margins into 'hälleflintas'.

It is next shown that the whole succession has been thrown into folds with axes trending north-east and south-west, and now lies in folded sheets with a low dip, though the bedding dips are high. This folding having been determined, it is possible to decide the relationship of the Coniston Limestone Series to the underlying beds. Near Millom the Upper Tuffs and Stile End Beds are developed. The latter are composed of detrital igneous matter. At Waterblean the Stile End Beds disappear. At Graystone House, near Duddon Bridge, where an important exposure of fossiliferous limestone was discovered among the volcanic rocks by Sedgwick, the Upper Tuffs are also absent. On the east side of the estuary mapping shows the limestone lying upon the Dog Crag type, the mottled shale, and the blue shale or andesite. The conclusion that an unconformity exists was confirmed by a trench cutting Coniston Limestone resting upon undisturbed intrusive augite-andesite.

The existence of a powerful strike-fault is proved by the position of the Graystone House Limestone and by repetition of the upper part of the volcanic group.

April 17, 1912.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The President announced that the Council had awarded the Proceeds of the Daniel-Pidgeon Fund for the present year to Otway H. Little, M.A., Royal College of Science for Ireland, who proposes to investigate the chemical and mineral changes which have taken place in the metamorphic limestone of Connemara.

The following communications were read :—

1. "The Pre-Cambrian and Cambrian Rocks of Brawdy, Hayscastle, and Brimaston (Pembrokeshire)." By Herbert Henry Thomas, M.A., B.Sc., Sec. G.S., and Professor Owen Thomas Jones, M.A., D.Sc., F.G.S.

The district dealt with in this paper lies about eight or ten miles to the east of St. Davids, and consists of pre-Cambrian plutonic and volcanic rocks surrounded by, and intimately associated with, sedimentary rocks of the Cambrian System.

The pre-Cambrian igneous and pyroclastic rocks are brought to the surface along an anticlinal axis which ranges in an east-north-easterly and west-south-westerly direction, that is to say, approximately parallel to the ancient ridge of St. Davids. They are distributed over an area measuring about nine miles in length by two miles in greatest breadth.

The pre-Cambrian rocks are divisible into two classes, an older volcanic series and a newer plutonic and hypabyssal series, for which Hicks's names of Dimetian and Pebidian are respectively retained.

The authors have not attempted any detailed subdivision of the Pebidian over the whole area, but it is clear that several stages are represented. The lower exposed portion is generally andesitic in character, the upper being rhyolitic and keratophyric.

The Dimetian comprises granite, quartz-porphyry, and diorite, which are intruded into the Pebidian, and present a common feature in the abundance of soda-felspar. Petrographical descriptions of the various pre-Cambrian rock-types are given.

The Cambrian has been divided into two main groups—the Welsh Hook Group below and the Ford Beds above. The Welsh Hook Group compares bed for bed with the Caerfai and Lower Solva Series of Hicks, and, like similar beds at St. Davids, consists of basal conglomerate, green sandstones, red shales, and purple sandstones.

The position of the Ford Beds, which are mostly shales, is not so certain; but the evidence is in favour of their belonging to the Upper Solva stage, and their having transgressed lower members of the Solva Series.

The basal bed of the Cambrian apparently rests upon rocks of different ages in different parts of the district; and this fact, taken into consideration with other evidence, indicates that the Cambrian reposes unconformably on a complex series of tuffs and lavas and of plutonic rocks intruded into these volcanic rocks.

The structure of the district is that of a horst, faulted on all sides and surrounded by much younger beds. The main fractures follow

an east-north-easterly to west-south-westerly direction, but frequently branch and run together, thus enclosing lenticular masses.

Much of the faulting is of pre-Carboniferous age, but that it continued into Carboniferous times is shown by the manner in which the Carboniferous rocks of the district have been affected.

2. "The Geological Structure of Central Wales and the adjoining region." By Professor Owen Thomas Jones, M.A., D.Sc., F.G.S.

This paper deals with the structure on a large scale of an area of about 1,800 square miles, comprising the western portion of Wales between the River Dovey and South Pembrokeshire. In an historical introduction the work of earlier observers, notably Sedgwick, Ramsay, and Walter Keeping, is referred to.

The paper is accompanied by a map whereon is indicated the distribution of certain rock-groups: this map is based partly on personal observations and partly on information gathered from various publications.

On the map the structure of the area is easily perceived. There are two principal anticlinal axes which follow in the main the valleys of the Teifi and the Towy, and are named after these rivers; between them is an important syncline (the Central Wales Syncline) which coincides nearly with the principal watershed of Central Wales.

Both the anticlines can be traced towards Pembrokeshire, where they appear as important structures; but they cannot be distinguished beyond the northern boundary of the area. The syncline, on the other hand, becomes more important in a northerly direction, but is lost towards the south-west. These structures have a southerly pitch at the northern end of the district, and a pitch in the opposite direction at the southern end. The variation in the pitch accounts for the form of the outcrops.

The peculiar correspondence between the evenly curved courses of these structures and the form of the coastline of Cardigan Bay, as also the relation of the structures to the other physical features, are discussed.

May 1, 1912.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The President referred to the loss which the Society had just sustained in the decease of Mr. Joseph Dickinson, at the age of 93. Mr. Dickinson had been a Fellow of the Society for no less than seventy years, having been elected in 1842, and he had retained undiminished to the last his keen and vigorous interest in geological and mining matters.

The following communications were read:—

1. "On the Geology of Mynydd Gader, Dolgelly; with an Account of the Petrology of the Area between Dolgelly and Cader Idris." By Philip Lake, M.A., F.G.S., and Professor Sidney Hugh Reynolds, M.A., F.G.S.

Mynydd Gader lies immediately south of the area described by the authors in a previous paper (Q.J.G.S., vol. lii, pp. 511–21, 1896). The Tremadoc Beds are here succeeded by a group of rocks which are

for the most part, of volcanic origin. These may be divided into a Rhyolitic Series below and an Ashy Series above. The Rhyolitic Series is formed chiefly of lava-flows; the Ashy Series consists mainly of volcanic ashes and slates, the ashes predominating below and the slates above. *Didymograptus bifidus* occurs near the base of the Ashy Series, *D. Murchisoni* in the upper part.

There is not sufficient evidence to show whether the Rhyolitic Series is conformable or unconformable with the Tremadoc Beds; but, since it lies between the *Dictyonema* Zone and the *Didymograptus bifidus* Zone, it belongs presumably either to the Lower or to the Middle Arenig. The Ashy Series extends from the Upper Arenig to the Llandeilo.

There are many intrusive masses of igneous rock, the largest being that which forms the greater part of Mynydd Gader itself. This intrusion is L-shaped in section, consisting of a horizontal limb which cuts across the beds, and of a descending limb which lies approximately in the bedding.

The petrology of the igneous rocks, not only of Mynydd Gader, but also of the area described in the previous paper, is dealt with.

The intrusive rocks are mostly dolerites, consisting chiefly of augite and plagioclase (labradorite-andesine), without olivine or rhombic pyroxenes. Epidote is very abundant as an alteration product. Contemporaneous veins are met with at one locality. Small intrusions of eurite occur just beyond the limits of the map.

The rhyolites are sometimes compact, sometimes banded, and sometimes nodular. Analyses of two specimens, the one compact and the other nodular, show that the percentage of soda is high.

The tuffs or ashes vary considerably in character. Some consist of a fine matrix with numerous scattered angular fragments of all sizes up to 18 inches; the fragments are mostly rhyolitic, but pieces of slate and grit also occur. In others the fragments are smaller, and some are so finely laminated that on freshly broken surfaces the texture appears perfectly uniform, but on weathered surfaces the lamination is often quite distinct.

Andesitic lavas occur at two horizons, in the Upper *Lingula* Flags and in the Llandeilo Series. The latter are often highly amygdaloidal.

The Rhyolitic Series appears to be older than the main mass of volcanic rocks in the Arenig area, but it may be contemporaneous with the *Calymene* Ashes of that district. It is probably of approximately the same age as the volcanic series of Skomer Island, and the fact that in both places the rhyolitic rocks are soda-rhyolites is of considerable interest.

2. "Insect-Remains from the Midland and South-Eastern Coal-fields." By Herbert Bolton, F.R.S.E., F.G.S., Director of the Bristol Museum.

The writer describes a series of three insect-wings obtained by Dr. L. Moysey, F.G.S., from the Shipley Clay-pit near Ilkeston (Derbyshire), and a blattoid wing and three fragments from the borings of the Kent Coal Concessions Company, Ltd., in East Kent.

The first series of insect-wings occur in greyish-brown ironstone

nodules, which lie in bands in a yellow clay about 30 or 40 feet below the Top Hard Coal.

The East Kent insect-remains occur in core shales, the horizon of which is not yet determined.

The wings obtained by Dr. Moysey are not referable to any known families. Three new families are formed to contain them, one of which is nearly related to the Dictyoneuridæ with some suggestion of the family Heliolidæ. A second new family is allied to the Heliolidæ, and the third new family to the Homoiopteridæ, or, as the writer believes, near to the Lithomantidæ.

The East Kent insect-remains contain one wing, referable to the genus *Soomylaeris* (*Ettoblattina*), a species of which is already known from the Forest of Dean Coal-field.

The finding of two species of the same genus in coal-fields so widely separated as those of the Forest of Dean and East Kent is not without interest, in view of the generally accepted belief in the former continuity of the Coal-measures across the South of England.

CORRESPONDENCE.

THE USE OF THE TERM 'CHARMOUTHIAN'.

Sir,—In the May number of the Geological Magazine for this year, on p. 232, the reviewer of Jukes-Browne's *Students' Handbook of Stratigraphical Geology* says: "The term Charmouthian for part of the Lias (pp. 383, 387) is used for the Middle Lias zones of the Ammonite genera *Paltopleuroceras spinatum* and *Amaltheus margaritatus*, whereas on p. 405 the term is taken to include also the Lower Lias zones of *capricornus* and *armatus*. This is unfortunate and no improvement. *As a matter of fact* [italics mine] the term is inappropriate as no Middle Lias (as above defined) occurs in the cliffs at Charmouth. If used at all the term should be applied to the Lower Lias clays (zones *obtusus* to *capricornus*)."

Surely, if used at all, the term should be applied to the beds included in the Charmouthian by the author of the term. This, according to Renevier,[1] was Mayer-Eymar, who proposed the term in 1864[2] and included within it the same beds as Oppel included in his Pliensbachian in 1858[3] and d'Orbigny in his Liasian in 1852,[4] namely, the zone of *Deroceras armatum* to that of *Paltopleuroceras spinatum* inclusive. Since these zones occur in the neighbourhood of Charmouth, I see no objection to applying the term with its original connotation, as Jukes-Browne appears to have applied it.

By the "Middle Lias (as above defined)" the reviewer presumably means the *margaritatus* and *spinatus* zones. To say that, as a matter

[1] Renevier, "Chronographe Géologique": Congrès Géologique international, Compte-rendu de la sixième session, 1897, p. 572.

[2] Mayer-Eymar, "Tableau synchronistique des Terrains Jurassiques," 1864. I have not verified this reference.

[3] Oppel, *Die Juraformation Englands, Frankreichs, und des Südwestlichen Deutschlands*, (1856)1858, p. 815.

[4] D'Orbigny, *Cours élémentaire de Paléontologie et de Géologie stratigraphiques*, vol. ii, p. 448, 1852.

of fact, no Lias of these zones occurs in the cliffs at Charmouth is untrue, unless "cliffs at Charmouth" is limited to Black Ven. Above a big gully immediately under the western end of Fairy Dell on Stonebarrow Cliff, within a mile of Charmouth Church, a section is exposed showing the Three Tiers at the base of *margaritatus* in place (last seen July, 1911); and, nearer Charmouth, in Stonebarrow Cliff west of the Dell, the lowest Tier with Ammonites of the *margaritatus* group may be seen. Incidentally it may be mentioned that the Three Tiers (as well as the beds immediately below down to the Belemnite Stone) are about half as thick here as at Golden Cap. The western end of Stonebarrow cannot reasonably be excluded from the "cliffs at Charmouth".

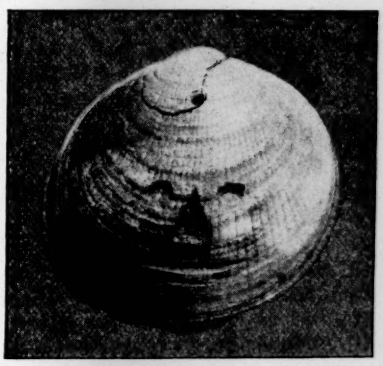
Renevier[1] held that, on account of priority, Pliensbachian should be used rather than Charmouthian. I am not aware that this principle is binding in stratigraphical nomenclature. But, whatever term finally is selected, there is no need either to shift the boundaries of Mayer-Eymar's Charmouthian or to object to the term on the score of topographical inexactitude.

W. D. Lang.

THE RED CRAG PORTRAIT.

Sir,—In the last number of the Geological Magazine (May, 1912) the Rev. O. Fisher figures some of the early handiworks of man. Among these is the sawn bone recorded as from the Crag, which was in Sir Joseph Prestwich's collection for many years and is now in the British Museum.

This reminds one not merely of the Red Crag portrait-shell, in which Sir Joseph was much interested, but accentuates the fact that this shell has never been illustrated. Consequently no figures of it are available for those who are interested, and its appearance is only known to our personal friends and some others who have seen it. Without repeating its history it must be mentioned in explanation



Carved Shell of *Pectunculus glycimeris*, Linn. Red Crag: Walton-on-the-Naze, Essex. Reproduced from a photograph, nat. size.

[1] Renevier, loc. cit.

that in 1881, when it was brought forward by Mr. Henry Stopes at a British Association meeting, it was considered *wrong* to suggest that man could have been alive at so early a date. Mr. Stopes was therefore content to wait till further evidence came to hand before bringing it before a wider public; but his early death left his work unfinished, so the shell has never been figured.

The accompanying illustration is from a photograph and indicates the natural size of the shell; it shows clearly most details of its features except the coloration. It should be noted that the excavated portions are as deeply coloured red-brown as the rest of the surface. This is an important point, because when the surfaces of Red Crag shells are scratched they show white below the colour. It should also be noticed that the shell is so delicate that any attempt to carve it now would merely shatter it.

As, however, the question is still so much under discussion, I wish to do no more now than give a good illustration of the most interesting, though controversial, specimen, so as to make its appearance and detail known to all interested in it. References to the literature will be found in my note in the Geological Magazine for February, 1912, pp. 95–6.

Marie C. Stopes (Ph.D., D.Sc., F.L.S.).

University College,
London, W.C.

OBITUARY.

RALPH STOCKMAN TARR.

Born 1864. Died March 21, 1912.

The sudden death of R. S. Tarr on March 21 last at the early age of 48 has been deeply felt by his many friends on this side of the Atlantic, who held in high regard his sterling personal qualities, as well as his scientific ability.

Born at Gloucester, Mass., Professor Tarr entered at Harvard in 1881, and after interruptions for practical work in marine zoology and for geological field-work in the Eastern and Western States, he graduated in 1891, and in 1892 was appointed Assistant Professor of Dynamic Geology and Physical Geography at Cornell University, and Professor of the same subjects there in 1896, occupying the chair of Physical Geography up to the time of his death. He was married in 1892, and leaves a widow and two children.

In 1896 Tarr had charge of the Cornell expedition to Greenland, which did excellent work; and in 1909 and 1911 he, conjointly with Professor Lawrence Martin, carried out the research expeditions of the National Geographic Society for the study of Alaska glaciers. In 1910 he participated in the Geological Congress excursion to Spitzbergen.

In his university Professor Tarr was recognized as an inspiring and sympathetic teacher, and his untimely death has called forth many touching tributes to his memory from his former students. He was the author of numerous papers and memoirs on physiography, glacial geology, and educational topics, the best-known in this country being

his fine monograph for the U.S. Geological Survey on the Physiography and Glacial Geology of the Yakutat Bay Region, Alaska, published in 1909. He also wrote several textbooks of physical geography, geology, and economic geology, which have had a wide circulation.

His arduous field-work in Alaska was resumed last year, and he was engaged in writing up the results and carrying out a series of experiments on the physical properties of ice when death cut short his labours.

Among other honours of recognition outside his own country, Professor Tarr was elected a Foreign Correspondent of the Geological Society of London in 1909.

G. W. L.

CHARLES EDWARD LEEDS, M.A.,

EXETER COLLEGE, OXFORD.

BORN AUGUST 11, 1845. DIED MARCH 27, 1912.

WE regret to record the death at Auckland, N.Z., of Mr. Charles Edward Leeds, M.A., formerly a solicitor in York, who made the early part of the remarkable collection of fossil reptiles from the Oxford Clay of Peterborough which now occupies so large a portion of a gallery in the British Museum (Natural History). Mr. Leeds attended the lectures of the late Professor John Phillips, M.A., F.R.S., and some of his earliest discoveries were described in the Professor's *Geology of Oxford and the Valley of the Thames*, 8vo, 1871, p. 318. Mr. C. E. Leeds left England in 1887 to spend the remainder of his life in New Zealand, and during the past twenty-five years the collection has been remarkably extended by his brother, Mr. Alfred N. Leeds, F.G.S., who still resides at his birthplace, Eyebury, Peterborough.—*Nature*, April 4, 1912.

MISCELLANEOUS.

THE HUMAN SKELETON DISCOVERED NEAR IPSWICH.—At the meeting of the Royal Anthropological Institute (50 Great Russell Street) on April 23, 1912, Professor Arthur Keith, M.D., F.R.C.S., and Mr. J. Reid Moir gave an account of the human skeleton found eighteen months ago in a brickfield near Ipswich.[1] Mr. Moir stated that the bones were earlier than any human remains so far discovered in England, and represented pre-Boulder-clay man. The theory of burial[2] he asserted was not possible, because the line which separated the overlying deposit of Boulder-clay and the underlying stratum of Glacial sand, in which the skeleton was found, was unbroken. The man was lying there before the clay was deposited. The flints found near were of *pre*-Palæolithic form.[3] Professor Keith said the skeleton

[1] See paper by Mr. George Slater, F.G.S., "Human Skeleton in Glacial Deposits at Ipswich," GEOL. MAG., April, 1912, p. 164; also letter by Mr. J. Reid Moir, op. cit., May, 1912, p. 239.

[2] See letter by Professor T. McKenny Hughes, M.A., F.R.S., GEOL. MAG., April, 1912, p. 187.

[3] See "Discovery of Flint Implements beneath the Red Crag in Suffolk", described by Sir E. Ray Lankester, F.R.S., GEOL. MAG., 1911, p. 576.